

FIRE RATING SEISMIC JOINTS

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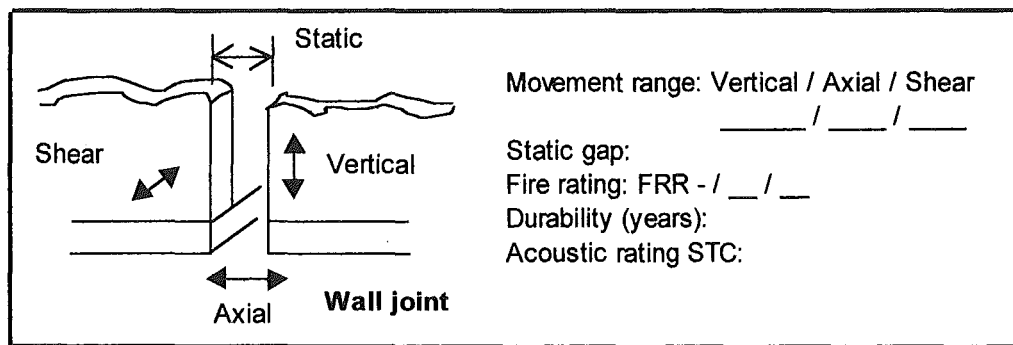
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ABSTRACT

This report reviews the design, selection testing, installation and performance of fire rated seismic joints from first principles then compares this with current standards and codes of practice around the world.

It reviews generic seismic joint designs in use today and the problems that can arise during the selection and installation phase of the job. It makes recommendations for areas of improvement in standards based on the first principle examination of joint requirements and actual selection and installation experience.

One of the key findings of the report is the need to clearly be able to convey the range of movement expected from a seismic joint to the manufacturer, designer, specifier, installer and later the building owner or maintenance or fit-out workers. To assist this a labelling system for joints has been developed and a web site produced to allow the viewer to dynamically see how joints move by inputting a range of movements.



Sample seismic joint label

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1 INTRODUCTION

1.1 Introduction

New Zealand is located on a fault line running from White Island in the Bay of Plenty down through Wellington then through the Southern Alps in the South Island. The moving continental masses on either side of this fault line cause earthquakes.

This fault line has also produced some desirable geological formations such as the Wellington harbour which has made it an attractive place to build a city. In times gone by buildings and earthquakes went together like water and oil. There are numerous examples of the disastrous consequences of building in an earthquake prone location.

However possibly due to relatively infrequent nature of major earthquakes and the desirable features of the land formations we have persisted in building in these areas. To try and mitigate the effects of earthquakes we have developed methods of building earthquake resistant buildings.

To a certain extent only time will tell whether our design assumptions are correct. We can look to how buildings have fared earthquakes in cities around the world to gauge the effectiveness of our own building designs. In Los Angeles, USA new buildings are instrumented to record the effects on the structure during earthquakes. Naeim (2000) has analysed the information gained from 20 instrumented building subject to the Northridge earthquake in 1994.

Now let us introduce another infrequent event called a fire. Fires in buildings occur independently of earthquakes. Fires on their own can have disastrous consequences with the loss of life and property.

To protect people and buildings from the effects of fire we have developed design strategies to minimise the risk of fires. These range from passive systems such as fire resistant floors, walls and safe escape corridors and stairs, to active systems such as sprinklers, hose reels, and fire hydrants.

Combining earthquakes and fires we have two scenarios. The first is buildings and fire protection measures being subject to the shaking of earthquakes and having to remain functional for a potential fire some time independent of when the earthquakes occur. The other is a fire immediately following an earthquake. The second although less frequent has historically caused devastating results as most active fire fighting systems are disabled due to ruptured water supplies, difficult access for the fire brigade to fight fires and disabled communication systems. This places a great reliance on passive fire protection systems.

Designing passive fire protection systems to withstand movement due to earthquakes has to be done in conjunction with the building design. Buildings can either be designed to be very strong and not move or be flexible and absorb

the energy of the earthquake. Buildings with a complicated shape may be divided into a series of smaller structures which all move independently. Modern building design uses a combination of these methods.

Passive fire protection features can also be designed to be flexible and absorb the energy or very strong to resist the movement. Often they are designed to be rigid then connected together with flexible connectors. One example of this is when we want to have a floor between two independent building structures. The floors are rigid and we need a flexible connector to join the floor in each structure so the fire rated seismic joint is born to solve the problem.

This report reviews the design, selection testing, installation and performance of fire rated seismic joints from first principles then compares this with current standards and codes of practice around the world.

It reviews generic seismic joint designs in use today and the problems that can arise during the selection and installation phase of the job. It makes recommendations for areas of improvement in standards based on the first principle examination of joint requirements and actual selection and installation experience.

One of the key findings of the report is the need to clearly be able to convey the range of movement expected from a seismic joint to the manufacturer, designer, specifier, installer and later the building owner or maintenance or fitout workers. To assist this a labelling system for joints has been developed and a web site produced to allow the viewer to dynamically see how joints move by inputting a range of movements.

1.2 Objectives

The aim of this report is to clearly illustrate the performance requirements associated with the design, selection, testing and installation of seismic joints at a fundamental level. It is hoped that it will be of assistance to manufacturers, architects, structural and services engineers, installers, builders and building owners and their respective maintenance contractors alike.

1.3 Definitions

No study of a subject is complete without looking at the definitions of key words and phrases. The definitions of the words comprising the project title in terms of this report are:

Joint a connection between two or more building materials which allows relative movement between them.

Fire rated resistance of materials either individually or as a group (such as a timber frame wall) to the effects of fire and smoke. Resistance is measured in three areas; structural adequacy, integrity and insulation. Structural adequacy is the ability to support a structural

load during a fire. Integrity is the ability to not let smoke or flames through during a fire. Insulation is the ability to prevent heat flow from the fire side to the non fire side during a fire.

Seismic movement produced by earthquakes. In this report it also refers to the relative movement between building materials.

2 EARTHQUAKES

2.1 Seismic movement (earthquake) history

The earth's crust is divided up into a number of plates that are slowly moving due to convection currents caused by the molten rock below. Earthquakes are caused by sudden surges of these plates as they try to move in opposite directions. They do not move evenly along the join, so stress tends to build up until the plates move suddenly to relieve the build up of energy.

Historical evidence of where earthquakes occur and mapping of fault lines show where the most probable sites for earthquakes are. At this stage when an earthquake will occur and how big it will be can only be defined statistically e.g. the likelihood of a force 6 earthquake in Auckland may be 1 in 100 years.

Figure 2.1 shows fault lines marked on a map of the world.

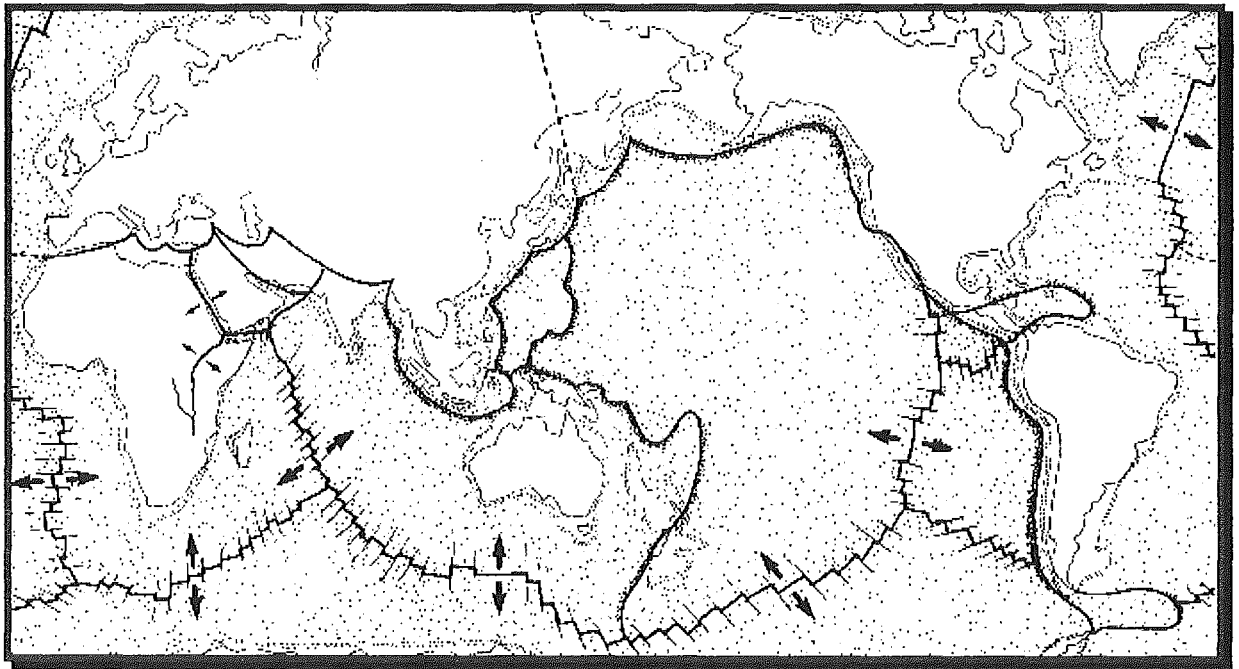


Figure 2.1 Fault lines around the world (Cox 1999)

The ten worst earthquakes by loss of life summarised by LTA (1989) are

1.	1556	Shensi, China	830,000
2.	1737	Calcutta, India	300,000
3.	526	Antioch, Syria	250,000
4.	1976	Tangshan, China	242,000
5.	1927	Nan-shan, China	200,000
6.	1923	Tokyo, Japan	140,000
7.	1730	Hokkaido, Japan	137,000
8.	1920	Kansu, China	100,000
9.	1290	Chili, China	100,000

10. 1201 Aegean Sea 100,000

Other significant recent earthquakes denoted by year and loss of life are:

1906	San Francisco	700 by quake and fire
1906	Valparaiso Chile	20,000
1933	Long Beach California	120
1966	Alaska	144
1985	Mexico City	8,000
1988	Armenia	25,000

New Zealand has fault lines running through it therefore is subject to earthquakes. Rogers (1996) reports the most notable recent New Zealand earthquakes denoted by year and loss of life are:

1848	Wellington/ Marlborough	3
1855	Wellington Wairarapa	6
1929	Murchison	17
1931	Napier Hawkes Bay	256
1942	Southern Wairarapa	1
1968	Inangahua	3
1987	Edgecombe	0
1990	Dannevirke	0

The low casualty rate can be attributed to the low population density. All of the above earthquakes measured 6.5 or higher on the Richter scale.

With the advent of modern scientific techniques it is possible to divide New Zealand up into regions with varying levels of risk dependant on how close they are to the fault line. Figure 2.2 from NZS 4203: 1992 graphically presents the level of risk for each zone.

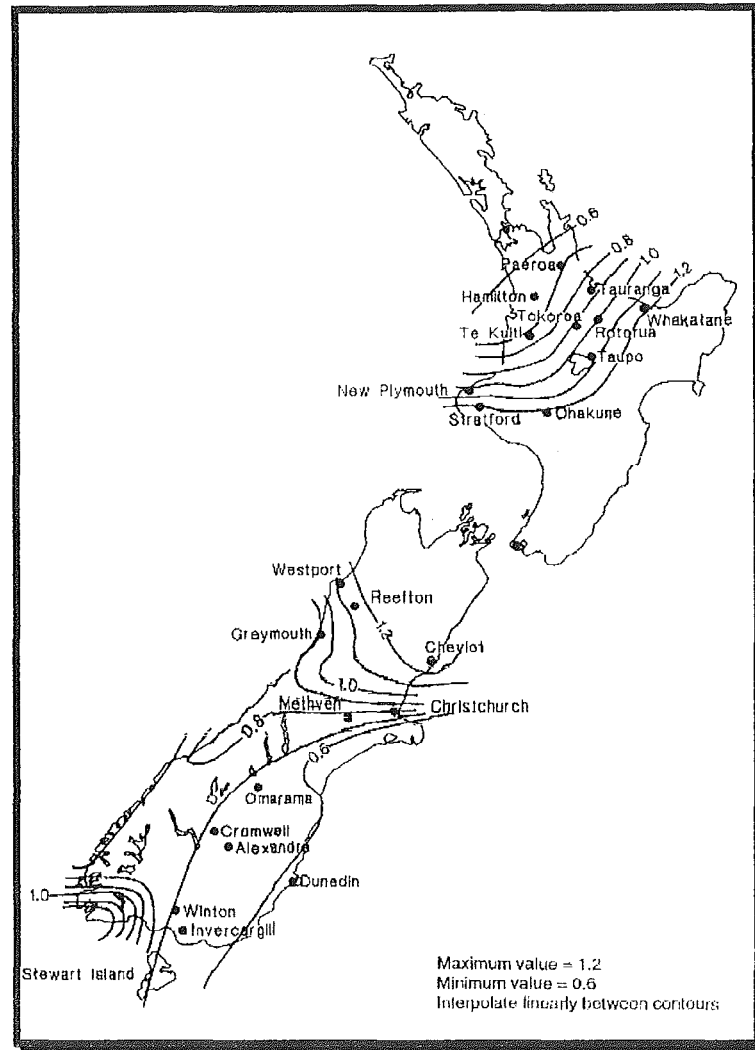


Figure 2.2 Seismic zones in New Zealand (NZS4203)

2.2 Impact of earthquakes on buildings

Earthquakes create shock waves that radiate out from the epicentre and cause the ground to move. The ground can move vertically and horizontally in any direction. Typically the major movement from a tremor lasts around 15 seconds.

Modern buildings are designed to move and absorb the energy of the earthquake. Movement is generally observed and felt as the building swaying from side to side. This can cause many permutations of deflection of the building shape. There is also vertical movement but as buildings are generally stiffer in this direction the movement is less observable. They move with a certain frequency dependant on their height, strength, stiffness, mass and floor plan area.

There are many publications on the impact of an earthquake on buildings after the event. If not designed strong enough they collapse. If they are not flexible enough they crack and fall apart to varying degrees. Figures 2.3 to 2.5 show the effect of earthquakes on a number of buildings. Figure 2.3 shows a number of

buildings collapsed after the Kobe earthquake, Figure 2.4 shows the failure of lower floors in an apartment building and Figure 2.5 shows office buildings in Kobe with a permanent lean after the earthquake.



Figure 2.3 Fire damage after the Kobe earthquake



Figure 2.4 Kobe Apartment building after earthquake



Figure 2.5 Kobe office buildings after earthquake

2.3 Fire following earthquakes

Apart from the structural damage that occurs to buildings during an earthquake the main fire fighting water supplies are often damaged. Depending on the level of structural and passive fire rating damage small fires can lead to large fires engulfing entire city blocks. Figure 2.6 shows damaged water mains flooding the streets with water.



Figure 2.6 Damaged water supplies after 1906 San Francisco Earthquake

Figure 2.7 shows how small fires in Kobe spread into a large conflagration when fire fighting water supplies and fire ratings were damaged.

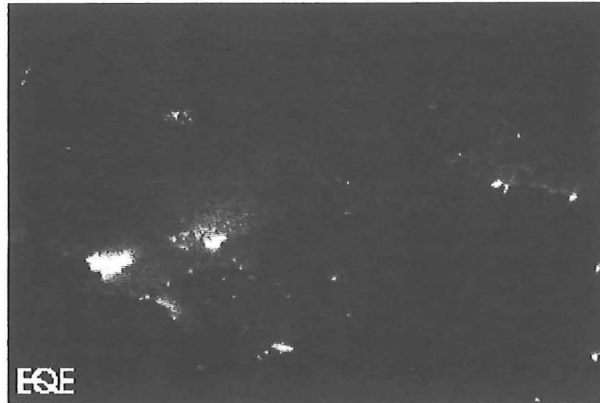


Figure 2.7 Kobe earthquake fire

Fire following an earthquake has been studied extensively by Botting (1998) and has been summarised succinctly by Botting and Buchanan (2000). Botting conducted an extensive study of 40 major earthquakes and selected 15 for special study which had significant fires reported. The fifteen have all occurred in the last 100 years.

Some of the ignition sources were

- Spills of flammable liquids.
- Toppling of equipment or electrical sources.
- Resuming electricity supplies too early.
- Arson either malicious or people trying to mitigate not having earthquake insurance with fire insurance.

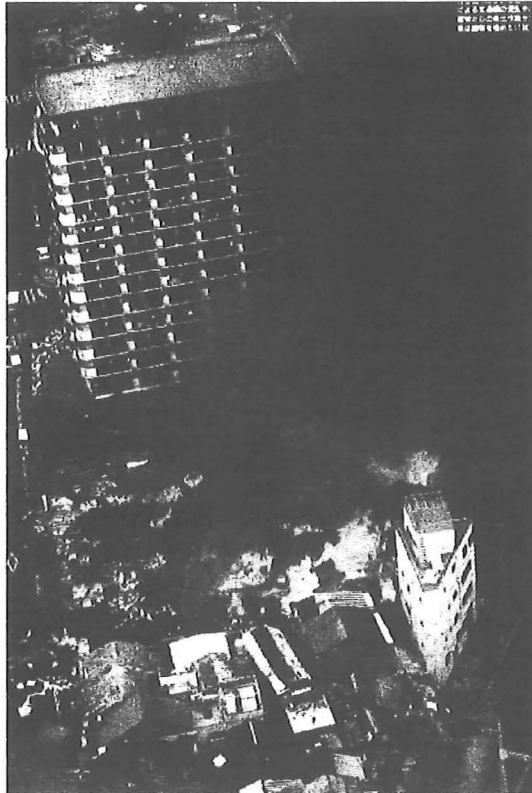


Figure 2.8 Fire after Kobe earthquake

Fire spread was assisted by

- Closely spaced buildings
- Poor fire ratings
- Wind
- Lack of communications
- Lack of water
- Difficulty for the fire service to reach fires due to building debris blocking roads.

Whilst it is difficult to quantify risk it would appear from Botting's research that the likelihood of fire following a major earthquake, particularly one where water supplies are damaged, is high.

3 SEISMIC JOINTS AND MOVEMENT

3.1 Where does seismic movement occur in buildings

Buildings of irregular shape such as L shape have different parts wanting to move in different directions at once. Considerable strength is required to make them all move together and it is often more cost effective to construct the building as two separate buildings and allow them to move independently (Figure 3.1).

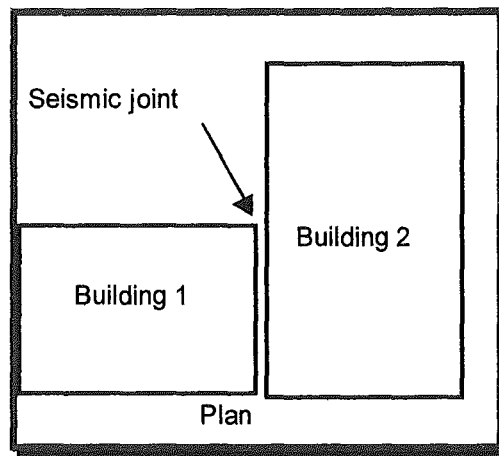


Figure 3.1 Building consisting of two structures

Another scenario is when adding a new section to an existing building the most economic design for the new section may not match the range of movement of the existing building (Figure 3.2).

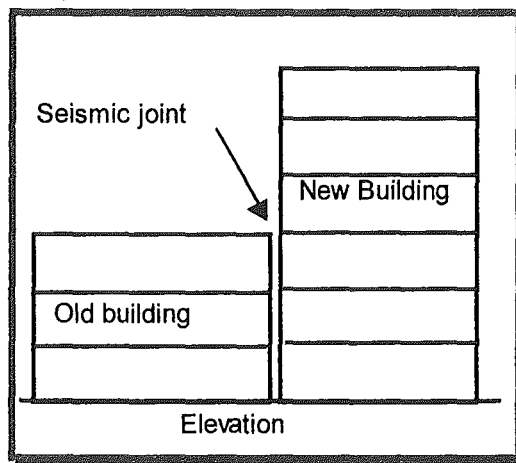


Figure 3.2 Seismic joint between new building and adjacent old building

The joint between the buildings does not need to be in a straight line (Figure 3.3).

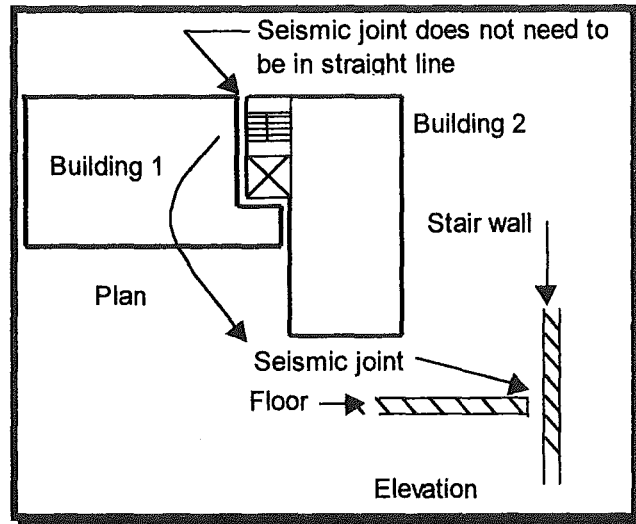


Figure 3.3 Joint between buildings not in a straight line

Other areas where seismic joints are used are seismic frames around windows, gaps between external precast panels, thermal expansion joints on large slabs, and, between internal partition walls and the supporting slab above. Refer to Figures 3.4 to 3.7.

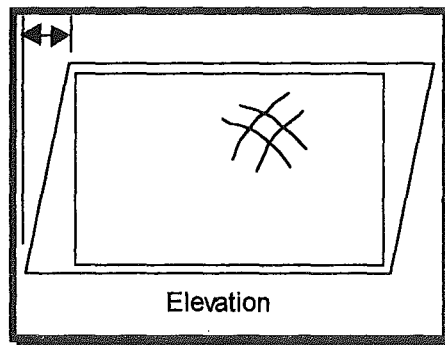


Figure 3.4 Seismic joint around window frame

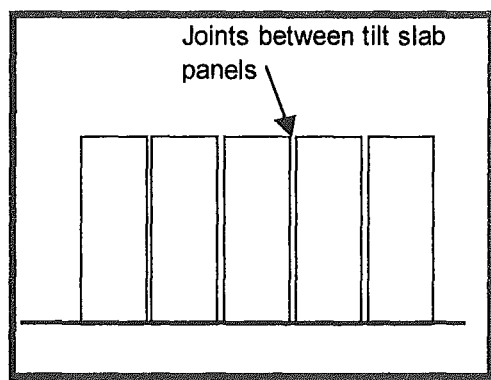


Figure 3.5 Joints between pre-cast panels

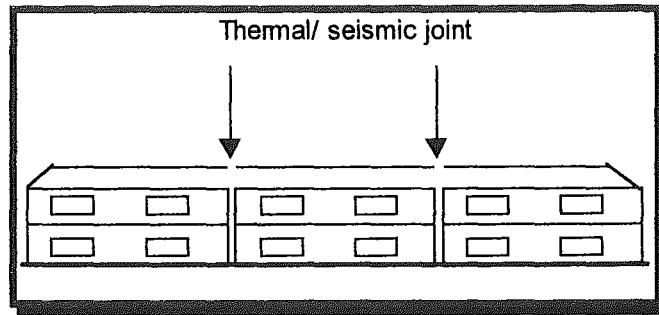


Figure 3.6 Thermal expansion joints in large flat slabs

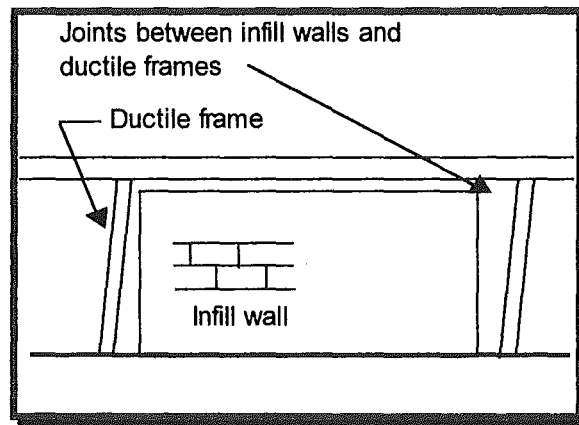


Figure 3.7 Joints between building structure and infill walls

Seismic movement will also occur between different buildings having a walkway between them as shown in Figure 3.8.

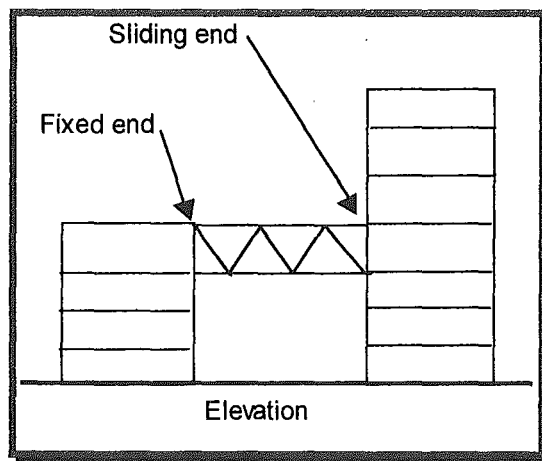


Figure 3.8 Walkway between different buildings

3.2 What type of movement can occur?

A single building subject to an earthquake is going to deform mainly in the horizontal plane. The vertical members will deform more at the base of the building than at the top off the building. As can be seen from Figure 3.9 there

will also be some vertical movement but this will be slight. For New Zealand style buildings (most less than 10 storeys) the vertical movement will be low and for two storey and lower it can be ignored.

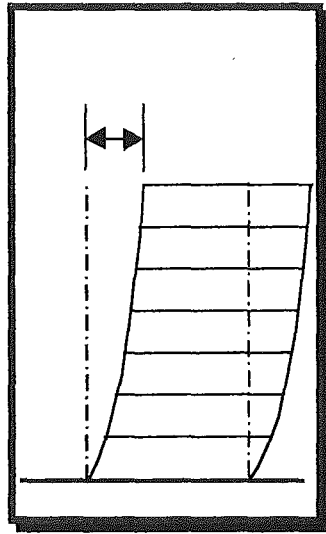


Figure 3.9 Horizontal building deformation

In very tall buildings there will also be a significant amount of flexural deflection. Two tall buildings side to side will have differential horizontal movement plus vertical movement.

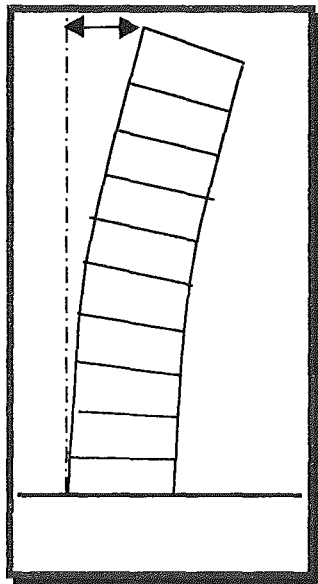


Figure 3.10 Flexural movement in tall building

The magnitude of these movements is covered in more detail in chapter 7.

3.3 When are fire rated seismic joints required

Not all seismic joints require fire rating as can be seen in figure 3.11. Where the two buildings are not connected, the fire rating is achieved by fire rating the

walls facing each other.

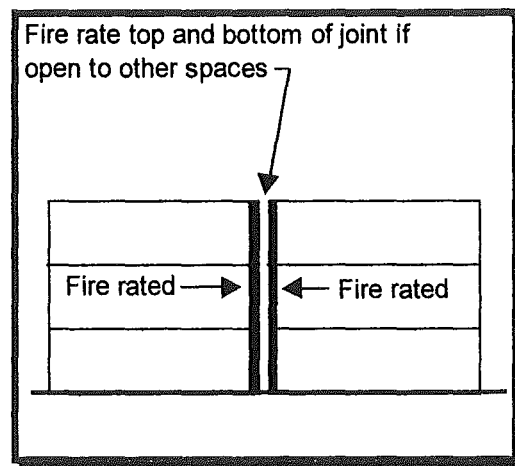


Figure 3.11 Fire rated walls either side of seismic joint

However the wall itself may require fire rating as shown in figure 3.12 if it consists of a number of pre-cast panels which will move differently to each other.

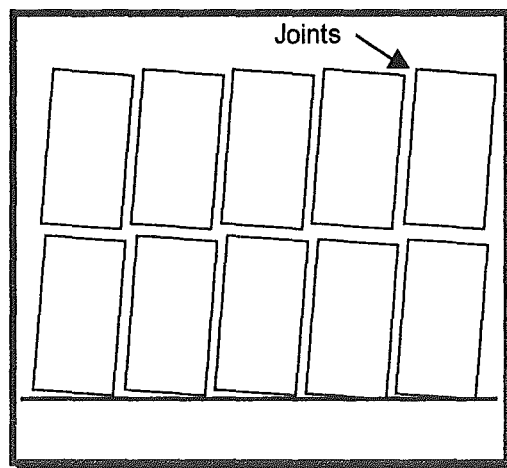


Figure 3.12 Joints between precast panels

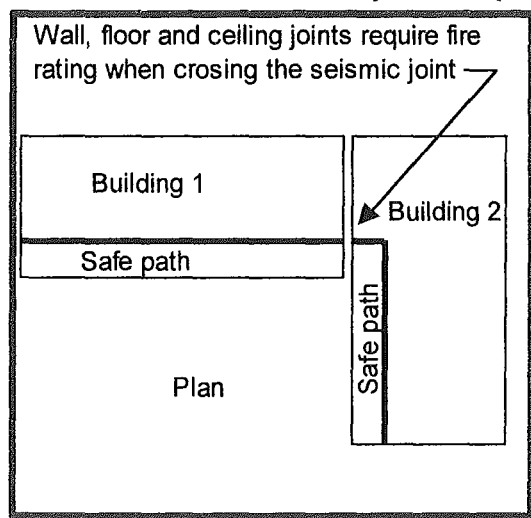


Figure 3.13 Safe path between separate part of building structure

If access is required between the two buildings (Figure 3.13) then a physical link is required between them. This will require connections for walls, floors, ceilings and roofs. Floors of a building are generally fire separated which require the floor and ceiling joint to be fire rated. The most common scenario for walls to be fire rated is if a fire protected corridor passes from one side of the building to the other side.

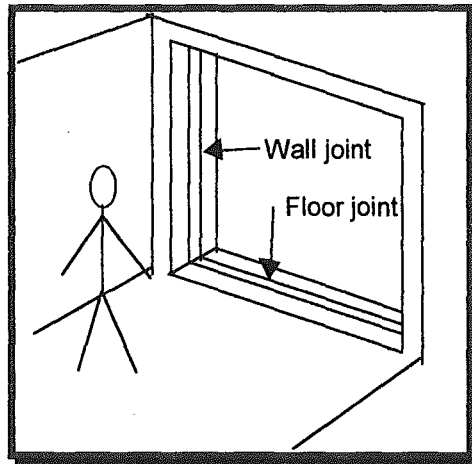


Figure 3.14 Fire rated corridor crossing seismic joint

It is worth noting that fire rated doors leading off the safe path corridor will be subject to seismic movement also as shown in Figure 3.15.

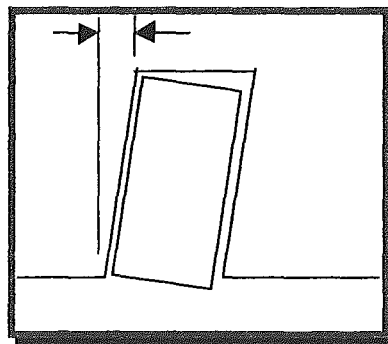


Figure 3.15 Fire rated door

Another scenario as shown in Figure 3.16 is when a firecell spans two separate parts of a building requiring the floor joint to be fire rated and similarly the wall joint where it crosses the floor joint (figure 3.17)

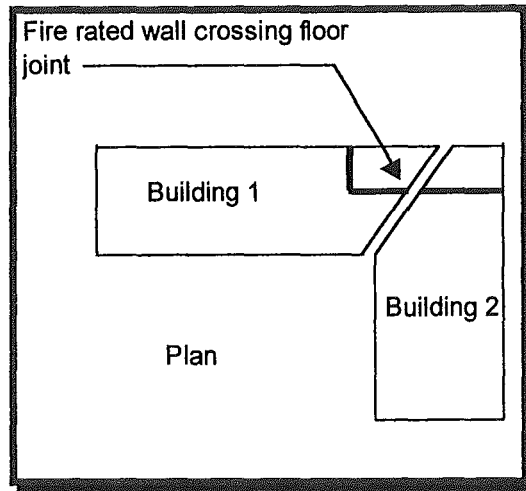


Figure 3.16 Fire cell crossing separate parts of building structure

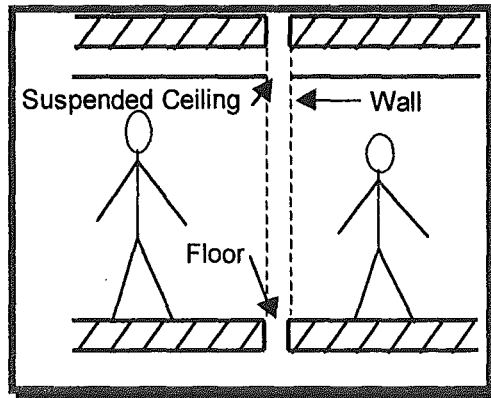


Figure 3.17 Wall crossing seismic joint

Fire rated seismic joints can also occur around services crossing a seismic joint. Figure 3.18 shows a pipe crossing a seismic joint. It can be seen that the design is such that the movement joint in the pipe is located inside the left hand side fire cell and there is relative movement as the pipe crosses the joint.

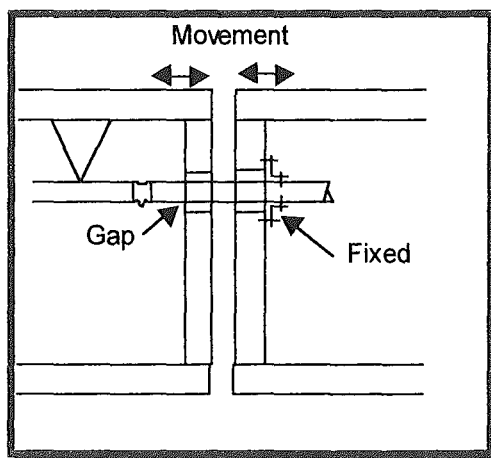


Figure 3.18 Services crossing seismic joint

4 HOW IMPORTANT ARE SEISMIC JOINTS ?

4.1 Background

Fire rated seismic joints as the name implies provide a fire barrier and fill a joint that can move during an earthquake. The question has to be asked whether they are important given the infrequent nature of earthquakes and fires.

When looking at the fire safety features in a building how important are fire rated seismic joints? Could they possibly be left out? Certainly in some areas earthquakes are very infrequent and in sprinkler protected buildings the risk of a major fire in a building particularly in New Zealand and Australia is very low.

This section takes a high level view of the part fire rated seismic joints have to play in a buildings fire protection system.

4.2 Analysis Methodology

There are a myriad of complex factors to be consider when analysing the performance of a fire protection system which makes it very easy to get bogged down in detail.

The process used to analyse the seismic joints is based on a computer software development process called the "Rational Unified Process" developed by Rational. The process is described and documented on their web site www.rational.com. Kruchten 1998 also documents it.

The process is driven by use cases that are identified end uses of the product. To test the usefulness of a product each use case is subject to timeline assessment of various good and bad scenarios to identify problem areas and weaknesses in the design. A key to quickly determining the strengths and weaknesses of each use case is rapid analysis and communication of ideas to potential end users and other experts in the field. This is achieved by using a visual model to describe the components and people involved in a use case and their interaction in each scenario. The process is an iterative one so the initial use case is very broad brush stroke and gets more detailed in subsequent iterations.

For this project the use case and scenario analysis is combined with visual modelling concepts to analyse the usefulness of fire rated seismic joints in a fire protection system.

To be able to rapidly produce and change use cases and timeline scenarios the drawing tools in Microsoft Excel have been used to build up a library of icons. Each worksheet in the spreadsheet is dedicated to a single use case or scenario. Icons are copied and pasted into the worksheets to build up each case.

Worksheets can be printed, turned into overheads or sent by email to others for comment. Due to the high level of integration between Microsoft Office products the pages can be imported into a Microsoft Powerpoint to provide a more controlled and professional presentation.

4.3 Importance

Three use cases for seismic joints have been examined.

- 1 A seismic joint installed in a building which has not been subject to an earthquake.
- 2 A seismic joint in a building immediately after an earthquake.
- 3 A seismic joint installed in a building that has survived an earthquake and is back in normal operation.

For these three use cases, worst case scenarios have been developed for fires in buildings that have no fire protection systems, manual alarms, heat and smoke detectors and sprinklers.

Figure 4.1 shows use case No 2 and Figure 4.2 shows the sprinklered building scenario as an example. The remainder of the use cases are included in Appendix A.

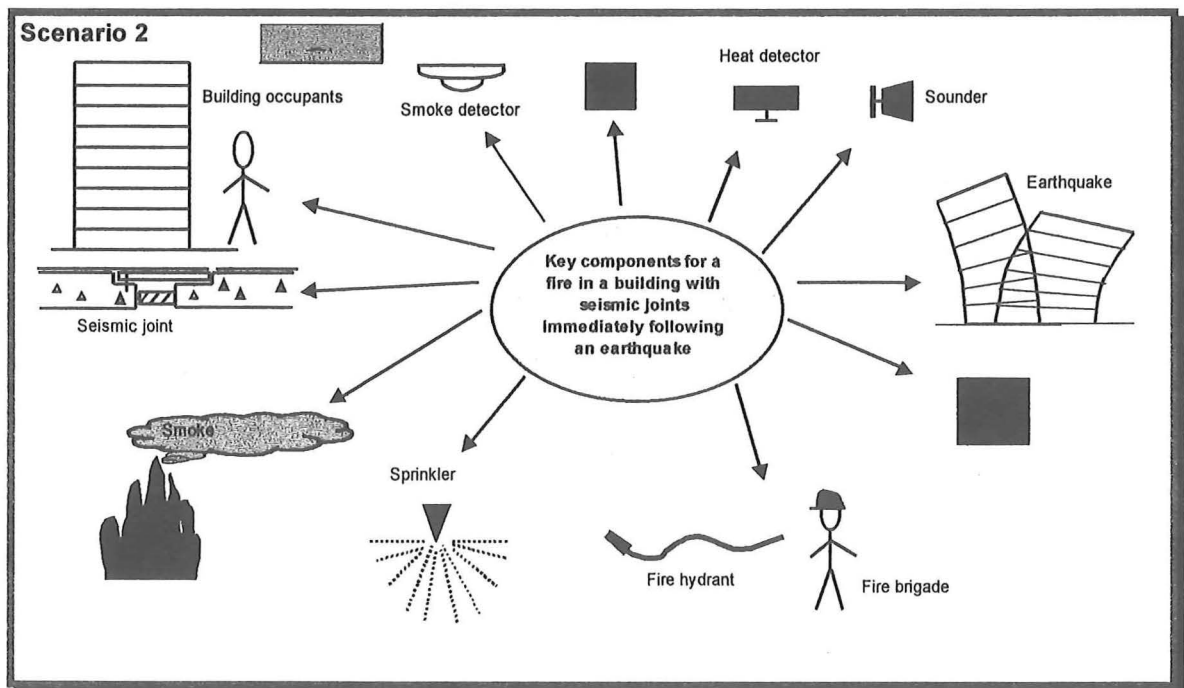


Figure 4.1 Building with no fire alarm

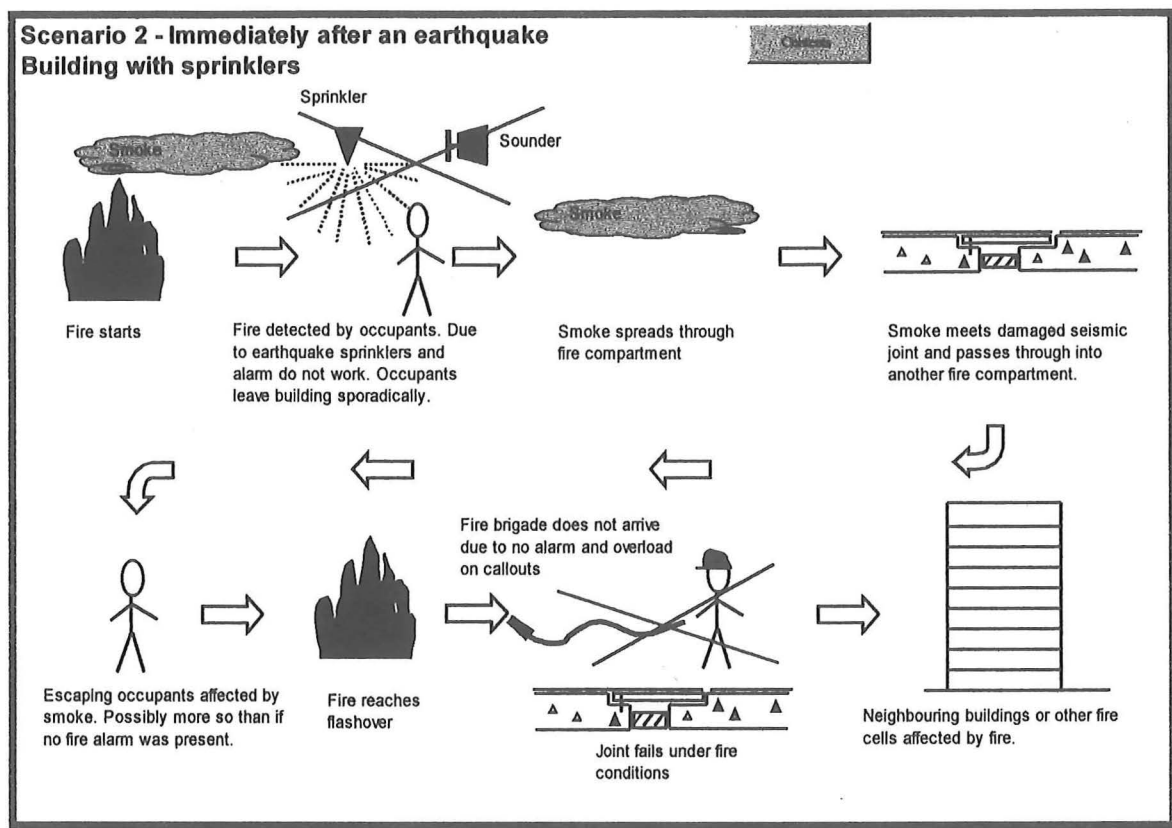


Figure 4.2 Building with sprinklers immediately after an earthquake

The scenarios depict the worst case where the joint fails to prevent the spread of smoke and fire. Failing to prevent the spread of smoke primarily has an adverse affect on building occupants, and failing to prevent the spread of fire can have an adverse effect on building occupants, as well as other fire cells and neighbouring properties.

For a building with no detection, alarm or fire suppression system the consequences of a fire in a building with failed seismic joints is the same whether or not the building has been subject to an earthquake.

For a building with an operational sprinkler system the consequences of the failed fire rated seismic joints during a fire are not significantly increased due to the excellent fire suppression ability of the sprinkler system

However immediately following an earthquake there is a high probability that the sprinkler systems may be damaged, it will not have a water supply and intervention of the fire service can not be counted on. In this case the consequences of failure are as high as or higher than an unprotected building as often dispensations are given to have lower fire ratings in a sprinklered building due to their good performance in fire suppression.

The impact on building occupants when a fire occurs immediately after an earthquake is greater for buildings where the detection, alarm and suppression systems have failed. The New Zealand Building Code Acceptable Solutions allow longer unprotected escape route lengths for active systems which provide

early warning and fire suppression.

Being overcome by the effects of smoke is the primary cause of death in a fire. In all scenarios the ability to prevent the spread of smoke in the early stages of a fire is the most important consideration for life safety. Activation of alarms and sprinklers helps minimise the consequences but can not totally eliminate the risk.

A seismic joint crossing a safe path could have serious consequences if it allowed the passage of smoke.

As a passive fire protection feature fire rated seismic joints are as important as any other passive fire protection feature in a building when considering that active systems such as detectors, alarms and sprinklers may not be operational after an earthquake.

Since seismic joints are generally in concealed spaces and not easily inspected their continued performance before, during and after an earthquake are important.

For life safety the prevention of smoke spread is the most important factor and should be able to survive the most demanding earthquake.

5 TYPICAL SEISMIC JOINT CONSTRUCTION

5.1 Floor/ Ceiling Joints

Figures 5.1 to 5.3 show typical seismic floor joints. Generic components shown in figure 5.1 are a fire rated element, a load bearing element and a final surface finish element. The fire rated element and load bearing element are designed to take up the differential movement between the two structures. The surface finish is often assumed to be sacrificial and will have to be replaced after a significant seismic event.

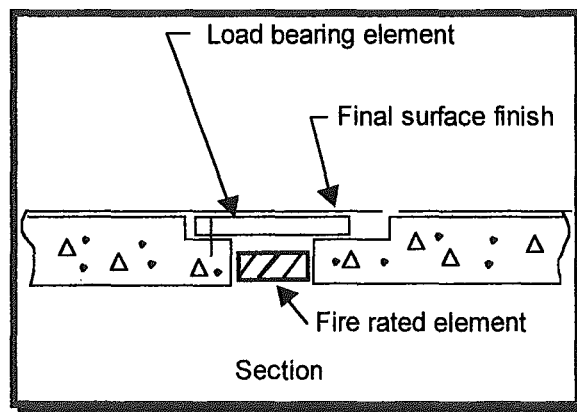


Figure 5.1 Generic floor joint components

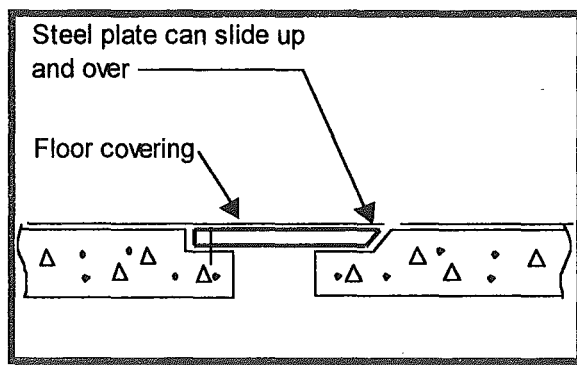


Figure 5.2 Steel plate load bearing element

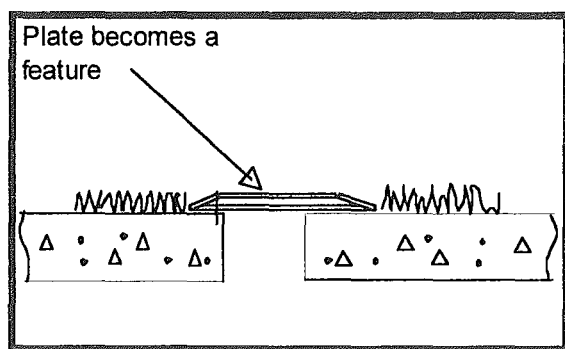


Figure 5.3 Load bearing element becomes a feature

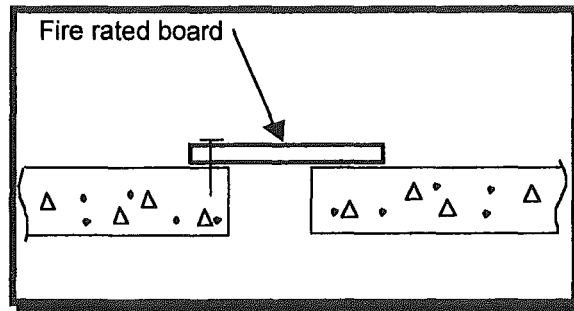


Figure 5.4 Fire rated board

The fire rated element can take the form of a board (Fig 5.4 and 5.5) which may have extra insulation added dependant on the performance criteria and materials used. The board can be placed on the top of the joint if for example it is in a cavity where there are no load bearing requirements. Normally when the joint is required to carry a load it is on the underside of the floor. It is pinned at one side and is allowed to slide on the other.

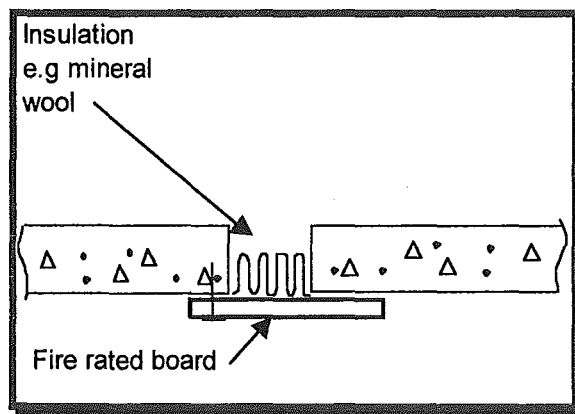


Figure 5.5 Mineral wool and fire rated board

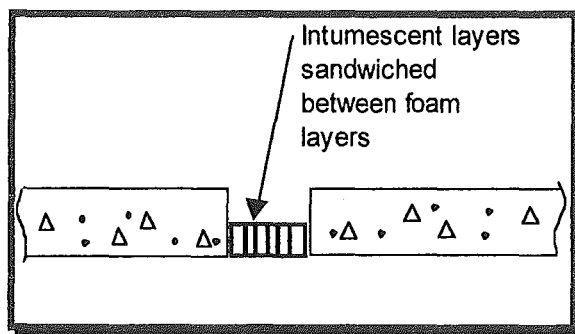


Figure 5.6 Foam/ intumescent sandwich

Intumescent layers sandwiched between foam layers as shown in fig 5.6 is often used in New Zealand but not widely used overseas. The strips are compressed into the seismic joint. During a seismic event the foam expands and contracts to take up the movement. In the event of a fire the foam also acts as a smoke

seal until the intumescent strips expand to fill the gap.

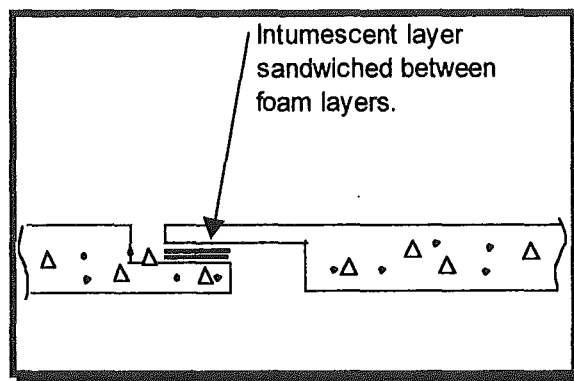


Figure 5.7 Slip joint

A slip joint can be used being formed out of the surrounding concrete floor structure as shown in figure 5.7. This is not a common design in New Zealand probably because it is difficult to build accurately. There is a bearing element between the two slabs to help them slide and a fire rated element.

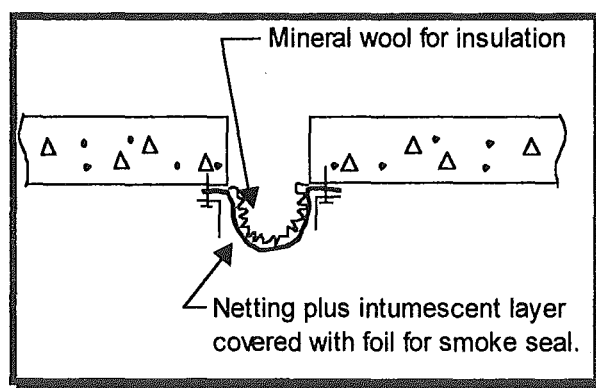


Figure 5.8 Blanket plus mineral wool

Another design is a fire rated blanket draped across the underside of the floor Figure 5.8. Imported products consist of netting holding together an intumescent layer with a foil covering. Local products consist of a mineral wool fire rated blanket. Often the cavity is filled with mineral wool insulation to provide additional insulation.

5.2 Wall Joints

Figure 5.9 and 5.10 show generic interior and exterior wall joints. They consist of a fire rated element and a surface finish element. The exterior wall also requires a waterproof element for the exterior wall.

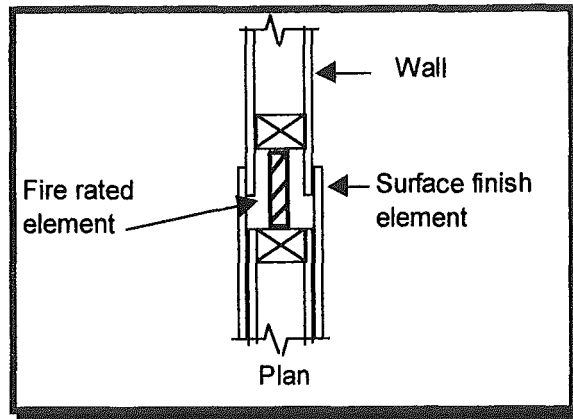


Figure 5.9 Generic interior wall joint

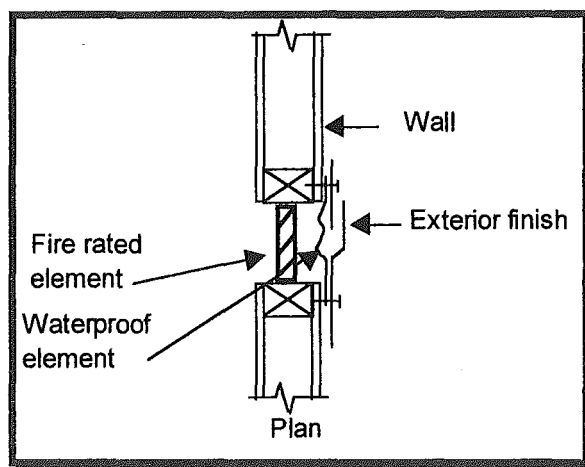


Figure 5.10 Generic exterior wall joint

Figures 5.11 through 5.16 show typical installations.

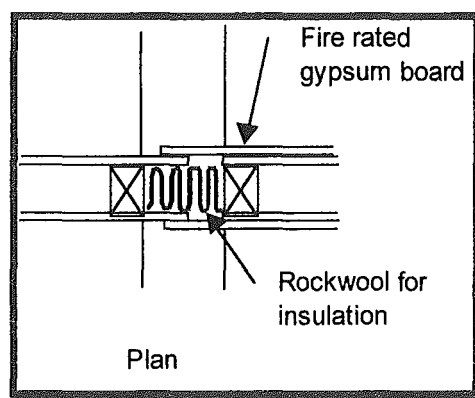


Figure 5.11 Gypsum board fire rating

Figure 5.11 shows a timber or metal stud wall with fire rated gypsum board on either side designed to take up axial movement. Mineral wool fibre can be placed in the centre for additional insulation.

Where movement is in a lateral as well as an axial direction which would damage the integrity of the gypsum board, a fire rated element such as an intumescent material sandwiched between foam strips, or a fire rated blanket can be used to provide the fire rating as shown in Figures 5.12 and 5.13.

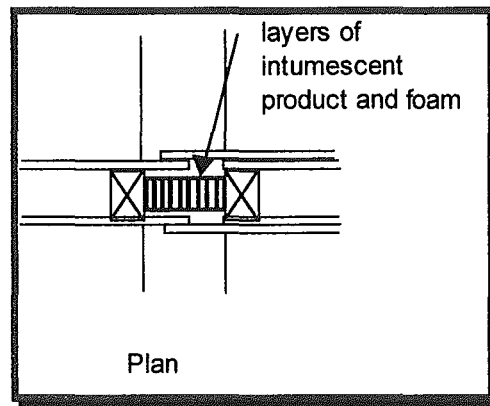


Figure 5.12 Gypsum board plus Intumescent strip

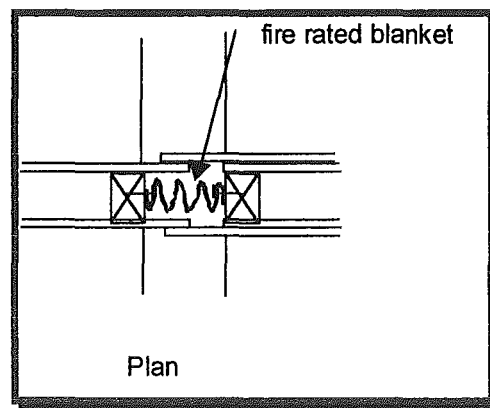


Figure 5.13 Gypsum board plus fire rated blanket

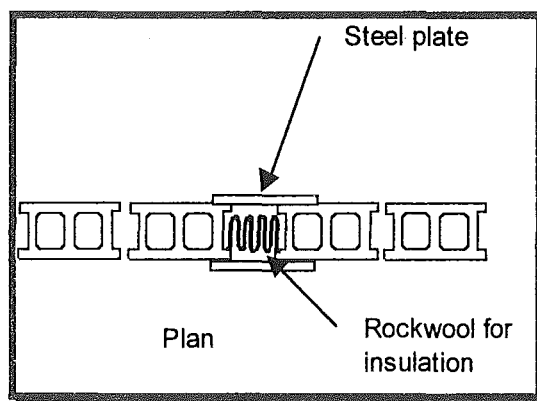


Figure 5.14 Steel plates and mineral wool

Figure 5.14 shows a concrete wall with sliding steel plates on either side providing the fire rating and mineral wool in the centre providing the insulation rating. Fire rated products as shown in Figures 5.12 and 5.13 could also be used

instead of the steel plate mineral wool combination.

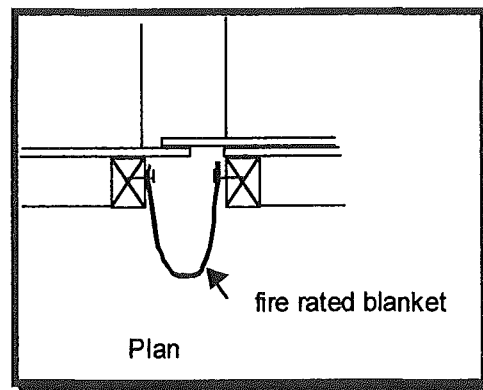


Figure 5.15 Fire rated blanket

Figure 5.15 shows a one way rated wall with a fire rated blanket providing the rating either in the form of mineral wool or intumescent product on netting.

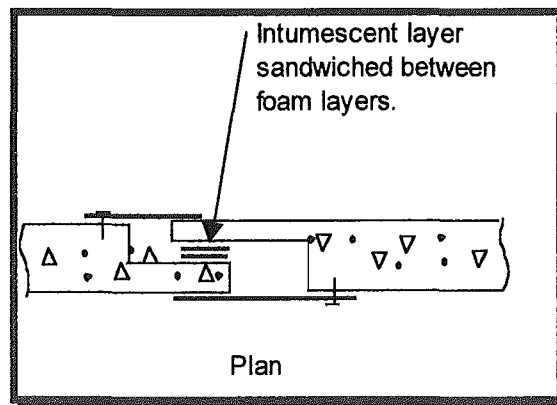


Figure 5.16 Sliding joint plus intumescent strips

Figure 5.16 shows a concrete wall overlapped to provide the fire rating. Sandwiched in between the two walls is a fire rated intumescent product, neoprene to allow movement and polystyrene to provide protection during construction and allow for construction tolerances.

6 JOINT FAILURE ANALYSIS

6.1 Observed and anecdotal problem areas

Seismic joints must meet a long list of criteria to be of any use. These are cost, fire rating, ease of installation, dealing with movement in up to three planes, moisture, acoustic properties. This section examines the pros and cons of the various joints to meet the fire rating criteria.

Fire rated boards

Fire rated boards are low cost and perform well when only subject to axial movement. The following are some areas where they do not perform well:

Maintaining integrity at corners is difficult (Figure 6.1)

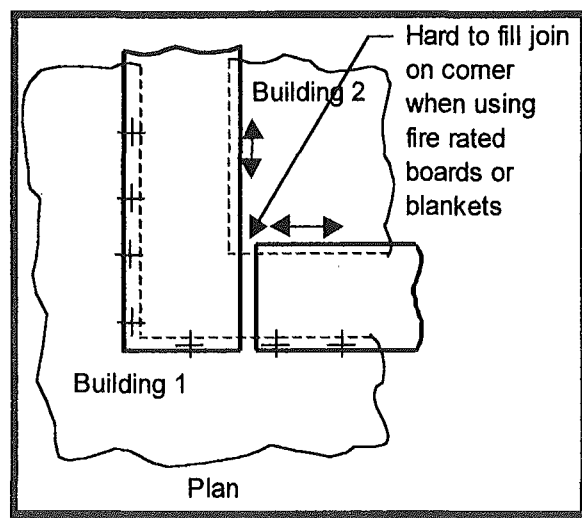


Figure 6.1 Corner joints

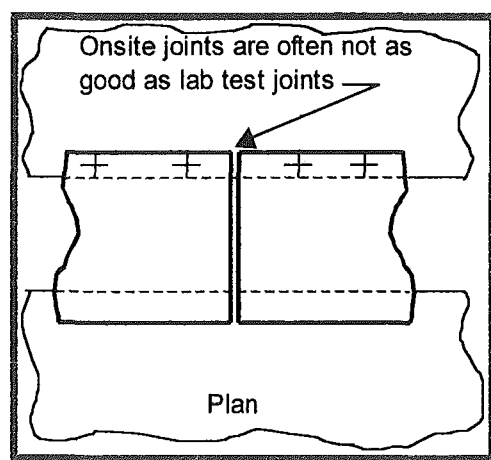


Figure 6.2 Onsite joints

On site joints are not as good as lab tests (Figure 6.2).

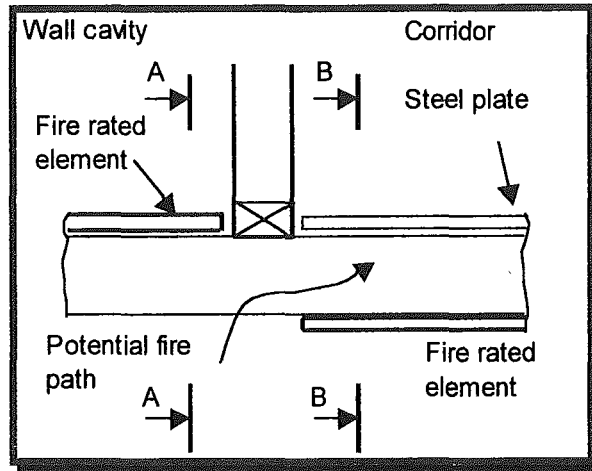


Figure 6.3 Elevation

The fire rating method can change along the length of the joint. Figure 6.3 shows a joint where a board has been used on top of the floor where the joint is concealed in a cavity. When it crosses a corridor the fire rated board is placed under the floor. Figures 6.4 and 6.5 are sections through the wall at these locations.

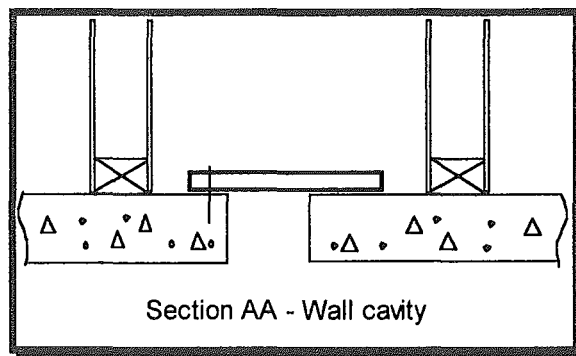


Figure 6.4 Section through wall cavity

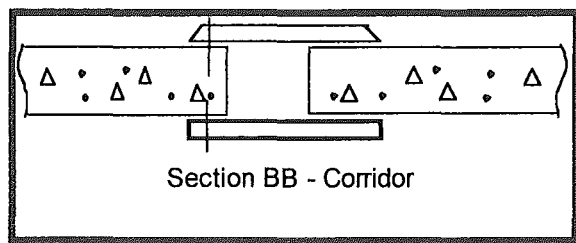


Figure 6.5 Section through corridor

The transitions from having the board on top of the floor to under the floor required something to rate the cavity at the transition.

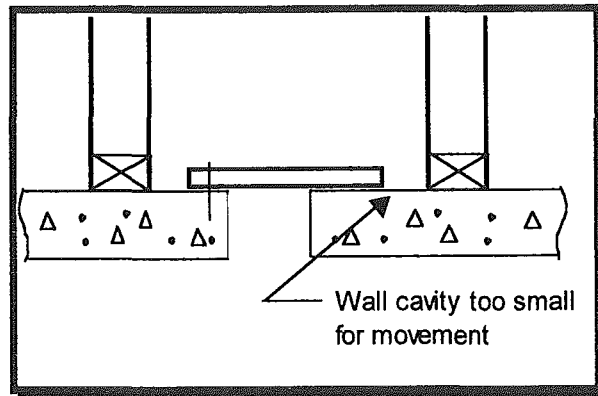


Figure 6.6 Wall cavity too small

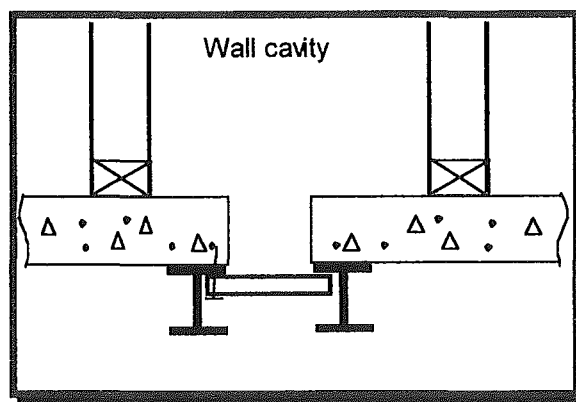


Figure 6.7 Space between beams insufficient to allow for movement

Insufficient space allowed for the movement of the joint (Figure 6.6 and 6.7).

Intumescent strips

Intumescent strips are relatively easy to install and due to the reliance on the intumescent strip to expand to fill up the available space they deal well with corners and movement in all directions. The most common problem areas are when the width of the seismic gap does not allow for the thickness of the strip when it is at its minimum width and when the gap is larger than the joint is designed for. This can occur when the building construction is different from the design and the specification of the intumescent strip is not rechecked. Using qualified installers is one way to overcome this, as they are more likely to spot that the product is not suitable for the application.

Slip joints

Slip joints (Figure 6.8) would appear to be able to perform well. The author has not observed any installed in New Zealand to be able to comment on their application and installation pitfalls

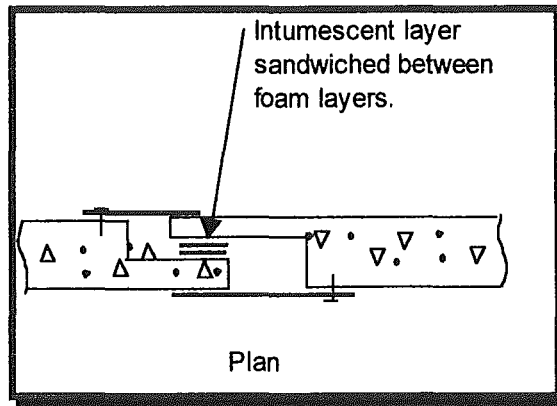


Figure 6.8 Slip joint plus intumescent strips

Fire rated blankets

Fire rated blankets as shown in Figure 5.15 perform well under axial movement but have problems with shear movement (Fig 6.9). They also have problems with joints and corners.

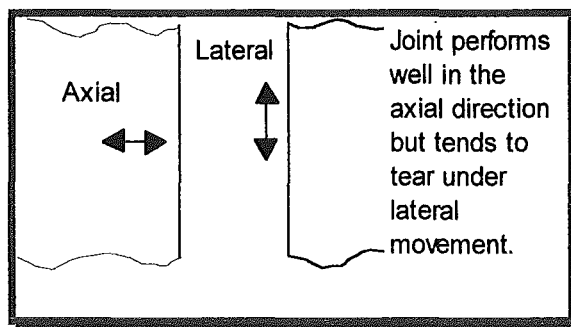


Figure 6.9 Lateral movement

When they are installed it is important that they are selected and installed to take up the maximum axial movement (Figure 6.10)

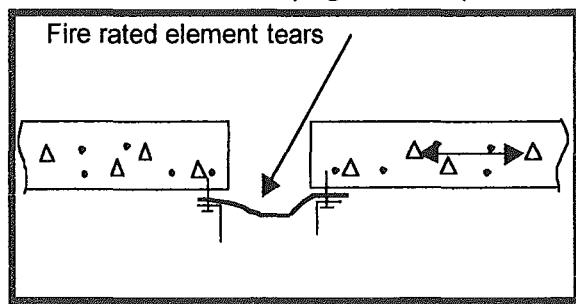


Figure 6.10 Insufficient slack

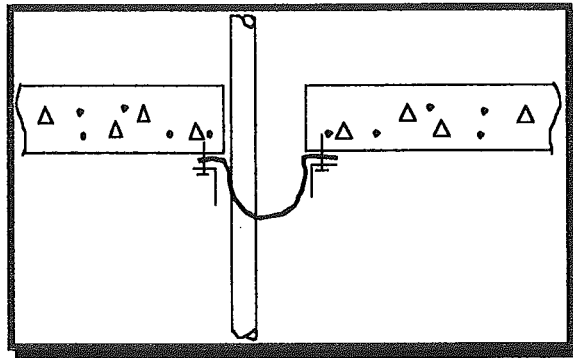


Figure 6.11 Services penetrate joint

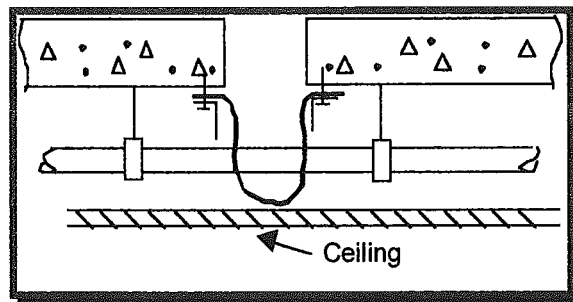


Figure 6.12 Services penetrate joint

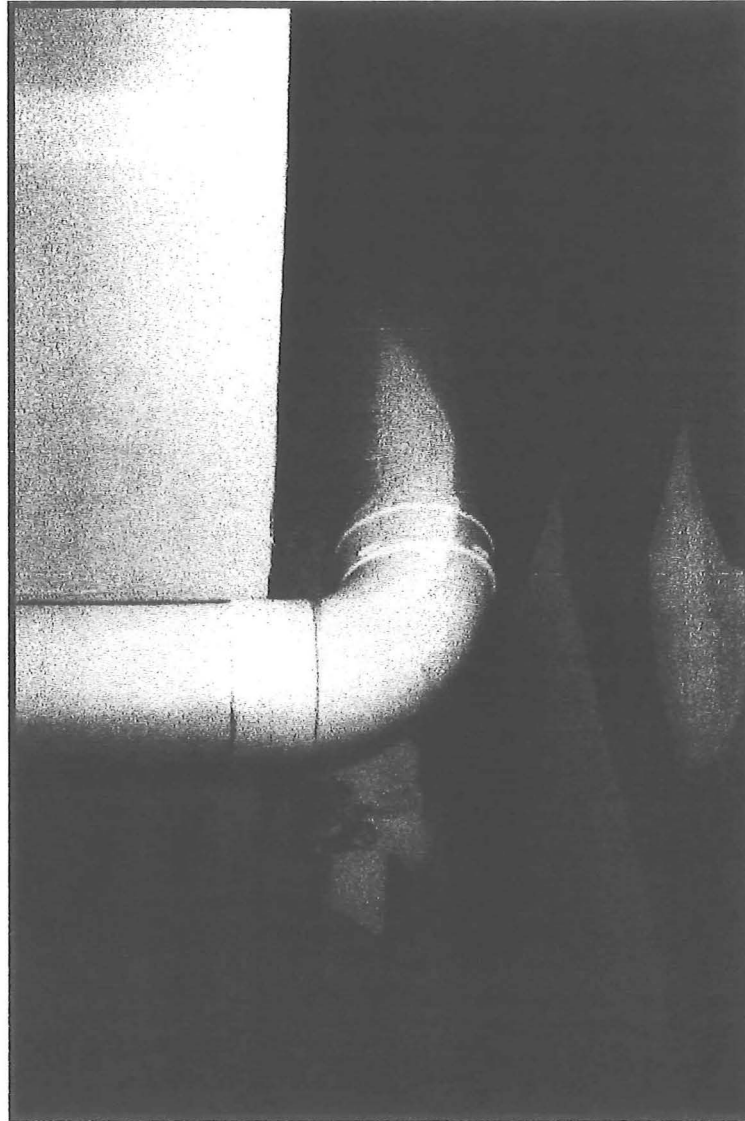


Figure 6.13 Services penetrate joint

Construction of buildings generally does not go totally to plan and often services are required to penetrate the seismic joint or barrier. Figure 6.11, 12 and 13 are examples. Most joints have difficulty dealing with this and have never been tested to see if they still maintain their rating. Intumescent products possibly perform better because they can fill up irregular shapes and cavities.

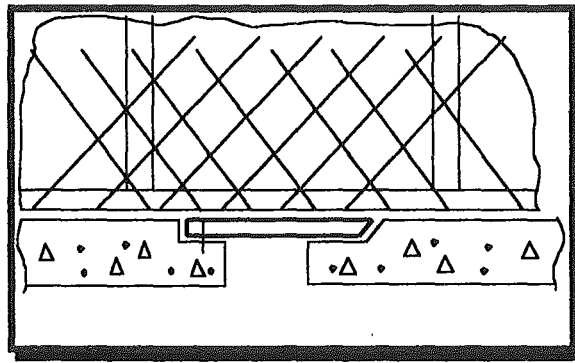


Figure 6.14 Wall built over joint

Another pitfall is that after a floor joint is installed and covered with the floor covering it may not be obvious that it is there. In this situation walls can be built spanning the joint as shown in Figure 6.14.

6.2 Historical failures

A well documented case of the failure of seismic joints is the 1980 fire in the MGM Grand Hotel in Las Vegas. Best (1982) reported that the building consisted of 3 wings separated by seismic joints 300mm wide. The gaps were covered with accordion fold steel plates and unrestrained metal floor plates. These coverings were not fire rated and did not seal the shaft. The seismic gaps opened to the interstitial space above the casino forming a continuous vertical shaft linked to the ground floor. In this fire, smoke was a major killer with 79 people dying and 61 of these were no where near the fire on the ground floor.

6.3 Specification and Construction reality

Fire rated seismic joints always look good in catalogues and perform well under their respective fire tests however the reality of selecting, specifying and installing a product can often be less than ideal.

In New Zealand the fire rated seismic joint is often considered to come under the architect's package of design responsibility. The general procedure is to obtain the expected movement from the structural engineer then seek advice from a manufacturer or sometimes a fire safety engineer. If the manufacturer is solely relied upon there is the danger that the architect without sufficient knowledge is unable to choose the correct product from the range being offered. Further down the track when alternatives are offered by the builder or required for cost saving measures the architect is offered further designs. Without a standard that specifically covers seismic joints it is difficult to choose between alternatives. even if they have test certificates of compliance with various standards. As will be discussed later in this report few standards cover the subject fully.

6.3.1 Cost

Fire rated seismic joints range in price from \$40 to \$500 per meter. Simple board systems cost \$40 to \$50 per metre, intumescent strip products approximately \$90 per metre and imported systems from \$300 to \$500 per meter. With this price range there is a lot of scope from the perspective of the client, quantity surveyor and builder to save money. Without a clear method of determining the relative merits of each system and their applicability to a specific situation the design is often changed to the lowest cost system. This can either be a conscious cost saving exercise at the initial stage of the design by the consultant team, or later by a builder. Often it occurs because the design team or the builder has overlooked the real cost of the joints at tender stage and there is pressure to cut costs to achieve budgets.

In New Zealand often expensive imported systems are specified but at the end of the day board systems are the norm with intumescent strip products being second. Some critical buildings such as the Auckland and Christchurch airports have more expensive imported systems.

6.3.2 Problems

Problems encountered during the construction stage based on the author's observations and anecdotal reports are listed:

- Once construction starts building tolerances can alter the theoretical gap the joint has to span. The author knows of one project where the gap changed from 100mm to 300mm due to construction tolerance that led to the chosen joint system being inappropriate for the gap.
- On another instance critical piped services were run up through the seismic joint rendering the chosen fire rating system useless. The cost and difficulty of relocating the services was more expensive than trying to design a solution to maintain the fire rating.
- Services are often strapped close to the under side of the floor slab prior to the installation of the fire rated joint to maintain high ceiling heights. When the joint comes to be installed the services interfere with the joint.
- Often a construction program may require the joint to be installed before the building is fully water tight or water leaks during the testing and installation of services can lead to water damage of the joints.
- The fire rating section of a joint is often installed prior to the outer protective cover which can lead to the damage of the fire rating which is not always identified and rectified.
- If an experienced installer does not install the joints they may be installed incorrectly.
- Splices and floor wall and ceiling interfaces look nice on drawings but are often a lot more difficult to achieve in practice. There always seems to be a building anomaly somewhere that prevents the standard installation from being used.

6.4 Failure analysis

This use case and scenario analysis combined with the visual modelling concepts is used to further examine the lifecycle of a fire rated seismic joint to locate areas where it may fail. Refer to Appendix B.

The life cycle of the joint is depicted in figure 6.15. It starts out with the joint manufacturer designing, testing, manufacturing and marketing a range of seismic joints then an architect or engineer specifies a joint or provides a performance specification. The builder tenders for the building, appoints subcontractors and commences building. Once the building has progressed to a certain stage the joint installer installs the joint. After the building is complete time passes, the building may be modified, maintenance work carried out, the joint will be subject to environmental conditions such as temperature, moisture and sunlight.

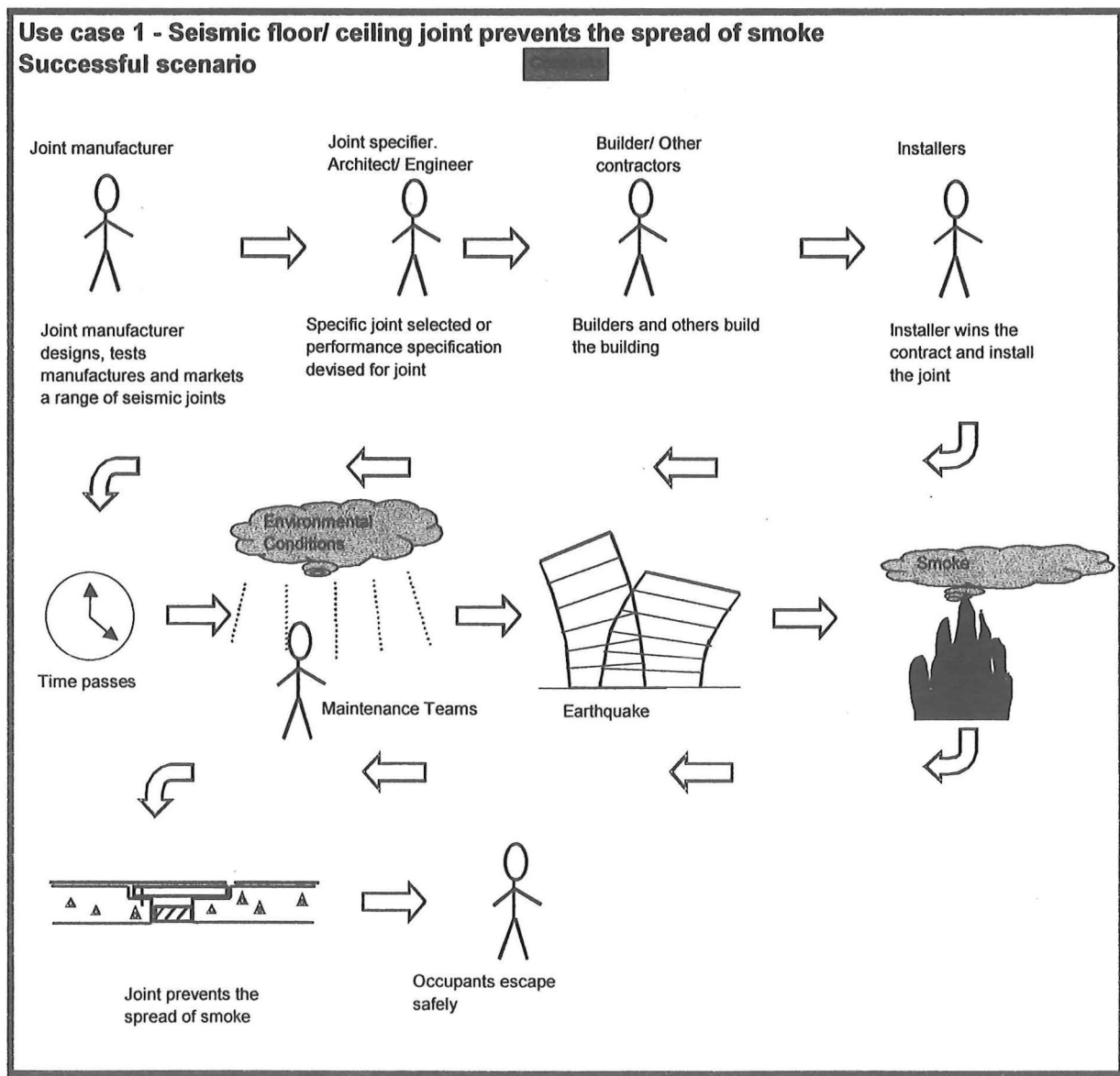


Figure 6.15

At some point there may be a fire in the building where the joint's smoke and heat penetration capabilities will be put to the test. Either before or after the joint may be subject to an earthquake of some magnitude. From here the joint may be replaced or remain in service for another indefinite period.

6.5 Critical areas

The life cycle of the joint undergoes a large number of phases during its life which all provide potential for failure to occur during a fire. Table 6.1 summarises the phases and the potential failure mechanisms.

Phase	Failure Mechanism
Joint manufacturer	Design standard not matching reality Testing standard not matching reality Incorrect application of products Manufacturing defects Damage during delivery Specification for supply incorrect Installation instructions inadequate
Joint specifier: Structural engineer Fire engineer Architect	Design features such as movement and smoke and fire rating not correctly communicated to the architect for specification. Incorrect joint selected for the application. Incorrect joint accepted as being acceptable when offered for approval by builder.
Builder/ other contractors	Gap built larger than joint designed for. Different joint chosen on price. Damage during construction. Other services pass through the joint.
Joint installer	Installation instructions incorrect. Mistakes made during installation. Installer not advised of required design movement. Joint specified is not able to deal with all the variations in the seismic gap.
Building owner/ occupier	Joints fail due to: Walls built over joints. Joints damaged during refurbishment projects. Joints removed due to inadequate knowledge of their purpose.
Passage of time	Joint products deteriorate due to age. Building is used beyond the expected life of the joint products.
Maintenance teams	No Maintenance. Damaged while other activities carried out. Services penetrating joints are altered.
Environmental conditions	Temperature. Moisture. Exposure to sunlight.

	Vermin.
Earthquake	<p>Earthquake larger than joint designed for.</p> <p>Movement is in directions not designed for.</p> <p>Joints not checked after a large earthquake.</p> <p>Damaged during building repair work after an earthquake.</p> <p>Repairs after an earthquake inadequate.</p>
Fire	<p>Inadequate smoke seals.</p> <p>Fire rating less than actual fire.</p> <p>Sprinklers are not operational so fire burns larger and longer.</p> <p>Fire rating less than actual fire.</p> <p>Sprinklers are not operational immediately after an earthquake so fire burns larger and longer.</p> <p>Water from sprinklers affect the performance of the joint immediately or in a future fire.</p>

Table 6.1

7 HOW MUCH MOVEMENT?

7.1 Direction and frequency of movement

When buildings are subject to an earthquake they sway from side to side. The primary mode of vibration is in the direction of the earthquake and the secondary mode is at 90° as shown in figure 7.1.

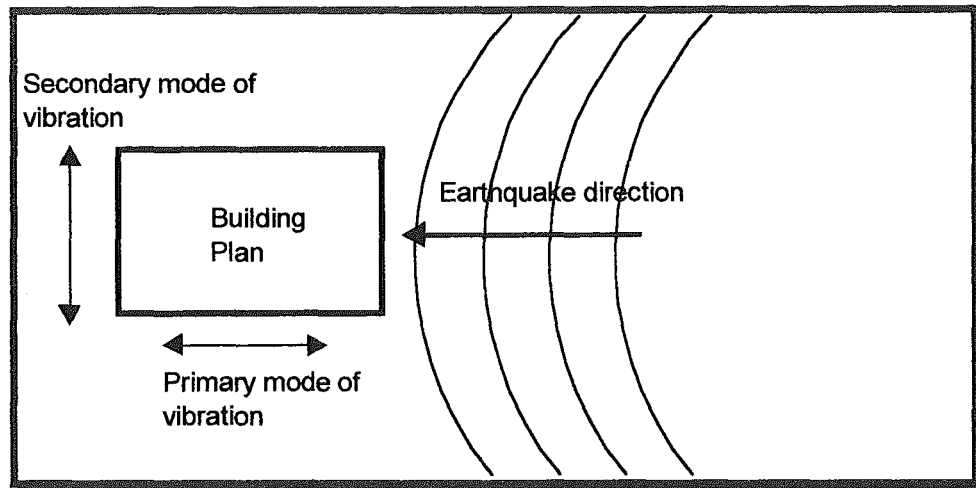


Figure 7.1 Modes of Vibration

Factors that effect the amount of movement for given size earthquake are the foundation design, the soil type, (whether it is sitting on rock or soil), the building construction and stiffness. Frame buildings allow a lot of movement compared to shear wall buildings. A building may also act as a frame building in one direction and a shear wall building in the other direction. The direction of the earthquake will also effect the magnitude of the primary and secondary modes of vibration.

The frequency of the movements is dependant on the stiffness of the building so two buildings subject to the same earthquake will most likely have different frequencies. Figure 7.2 and 7.3 shows the range of movements that might be expected between two or more buildings with earthquakes from different directions.

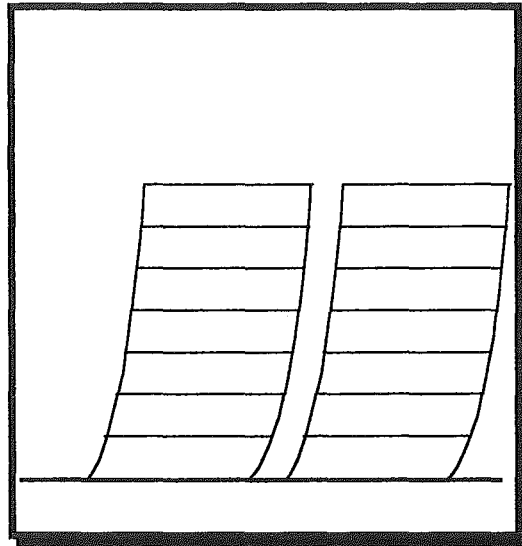


Figure 7.2 Earthquake parallel to seismic joint

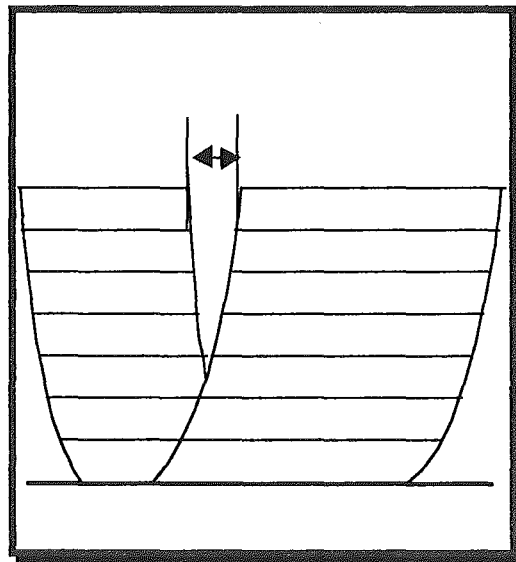


Figure 7.3 Earthquake perpendicular to seismic joint

Since two buildings are rarely constructed the same the movement frequencies will be different and hence the seismic gap will expand and contract. It can also be deduced that sideways movement between buildings can be as significant as movement towards and away from each other dependant on which direction the earthquake is acting.

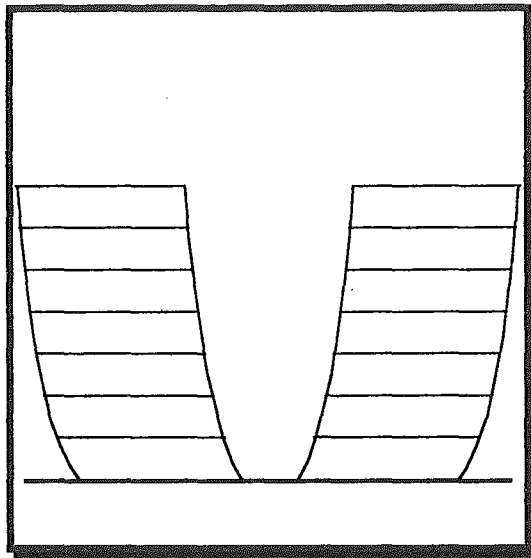


Figure 7.4 Earthquake parallel to seismic joint

All the standards for fire rated seismic joints only allow for movement in an opening and closing direction however most installations will also be subject to sideways or shear movement. Due to varying types of building construction, foundations and soil types as described above it is probably necessary to design joints that can take simultaneous opening and closing movements along with shear movement

7.2 Magnitude of movement

In New Zealand the movement required of a seismic joint is normally determined by a structural engineer. For new buildings structural engineers use NZS 4203 1992 for the design parameters. Existing older building require a structural analysis to be undertaken to determine the extent of movement. For other engineering disciplines guidance is given in NZS 4541 for sprinkler pipes crossing seismic joints and NZS 4219 for seismic restraint of mechanical systems and services crossing seismic joints. The latter two use the upper limit of allowable movement from NZS 4203 for their guidelines.

Table 7.1 gives maximum deflections for varying building heights under the serviceability and ultimate limit state design based on maximum inter-storey deflections given in NZS 4203. The slab to slab height is taken as 3.5m. The movements are for a single building therefore they need to be doubled to get the deflection between two buildings.

Floor	Building Height m	Ultimate Inter-storey deflection (mm)	Ultimate limit state deflection (mm)	Serviceability Inter-storey deflection (mm)	Serviceability Limit state deflection (mm)
1	3.5	70	70	12	12
2	7	70	140	12	23
3	10.5	70	210	12	35
4	14	70	280	12	47
5	17.5	67	348	11	58
10	35	53	600	9	100
15	52.5	53	862	9	144
20	70	53	1125	9	188

Table 7.1

It can be seen from the table that designing fire rated seismic joints for the ultimate limit state results in very large movements. Fire rated seismic joints would probably be classified under NZS4302 as category PI and PII parts (parts which could lead to loss of life and the continuing function is important). Therefore they would need to be designed for ultimate limit state movement for category I and II buildings i.e. buildings dedicated to the preservation of life and buildings containing crowds. Since the movements are so large the movements calculated by a structural engineer would be used rather than the upper limits given in the table above.

For buildings other than category I and II a reduced value could be used. Is the serviceability limit state sufficient or should the value lie somewhere between the serviceability and ultimate limit state?

Williamson 1998 has reported on procedures to be used to evaluate the safety of building after a major earthquake based on experiences from recent major earthquakes in particular the Northridge, California 1994 earthquake. After that earthquake all the buildings were evaluated for their suitability for occupancy and were given either a green "suitable for use", yellow "restricted access" or red "unsuitable for occupancy" tag. Within two weeks 67,000 buildings were inspected and after 6 months 113,000 buildings were inspected. To carry out this task 880 people were employed mainly civil engineers, many of whom were not fully conversant with fire safety requirements. Williamson identified the problem that some buildings were classified as suitable for use on a structural basis but would have failed for fire safety reasons. Considering the magnitude of the task it is probably unrealistic to assume a full fire safety evaluation will be carried out.

The state of California in America has a statutory requirement to place seismic monitoring equipment in buildings. Martin 1997 has taken the recorded data from 17 monitored buildings during the 1994 Northridge earthquake along with site observations and photographs to produce a CD ROM containing the data along with a variety of display and analysis tools.

Key data from 7 of these buildings is presented in Table 7.2

Building height	Duration (s)	Acceleration (g)	Velocity (cm/s)	Displacement (mm)	No cycles
Burbank, 10-story Residential Bldg. 21km from epicentre, built 1974					
1 st floor	30	0.3	19	32	6
4 th floor	30	0.4	22.6	39	6
8 th floor	30	0.41	40.65	42	7
Roof	30	0.52	31	46	9
Burbank, 6-story Commercial Bldg. 21 km from epicentre, built 1976					
ground	30	0.3	24	41	4
second	30	0.28	22.3	54	6
roof	45	0.27	44	112	24
Los Angeles, 17-story Residential Bldg. 32km from epicentre, built 1980					
1 st floor	40	.07	54	13	12
7 th floor	40	0.2	19.6	51	12
13 th floor	40	0.2	31	78	10
Roof	40	0.5	51	104	18
Los Angeles, 19-story Office Bldg. 20km from epicentre, built 1966					
4 th basement	60	0.2	15	48	14
1 st floor	60	0.24	16	49	15
2 nd floor	60	0.35	23	44	15
8 th floor	100	0.6	52	75	23
roof	100	0.6	73	250	22
North Hollywood, 20-story Hotel. 19 km from epicentre, built 1968					
Basement	30	0.3	36	81	6
3 rd floor	30	0.46	33.5	75	8
9 th floor	30	0.23	16.4	53	12
16 th floor	30	0.4	33	95	7
Roof	30	0.3	25	210	12
Sherman Oaks, 13-story Commercial Building. 9 km from epicentre, built 1965					
Basement - 2	45	0.2	29	87	12
Ground	45	0.37	29	80	13
2 nd floor	45	0.53	52	103	12
8 th floor	60	0.18	57	257	17
Roof	60	0.25	68	334	17
Sylmar, 6-story County Hospital. 16 km from epicentre, built 1982					
Ground	20	0.33	22	47	7
3 rd floor	20	1	124	310	3
4 th floor	20	1	126	309	3
Roof	20	1.5	134	339	3
Van Nuys, 7-story Hotel. 7 km from epicentre, built 1966					
Ground	30	0.4	35	117	9
2	30	0.37	37	132	10
3	40	0.45	46	163	10
6	40	0.33	61	227	13
Roof	40	0.57	79	212	15

Table 7.2 Northridge 1994 earthquake data

All of the buildings in Table 7.2 were suitable for reuse after the earthquake either immediately or after repairs. The Van Nuys 7 story Hotel building suffered severe structural damage that was estimated to take longer than 6 months to repair. The Sylmar 6 storey County Hospital suffered no significant structural damage but severe services damage, the Sherman Oaks 13 Storey Commercial Building had repairable structural cracks. The remaining buildings suffered non structural damage and damage to services to varying degrees.

Movement varied considerably from building to building, which can be attributed to the structural design and proximity to the epicentre of the earthquake. The two Burbank buildings had a 100% difference in movement yet were the same distance from the epicentre.

All buildings had movement greater than the serviceability limit state defined in Table 7.1 except the 10 story Burbank building and the 17 storey Los Angeles building.

In light of the fact that most of the buildings in Table 7.1 were subject to seismic movement greater than the serviceability limit state, it would be unwise to design fire rated seismic joints for this magnitude of movement if they are hidden from view. This would lead to buildings being structurally fit for re-use without being fire safe. On the other hand there is no point in over designing the joint for an earthquake that the building is not fit for re use. The ideal would be to design the joint to last slightly longer than anything that was concealing it so that it was exposed to view. Determining this limit is not a simple matter therefore a compromise may be to design for the serviceability limit state plus 20% for concealed joints and the serviceability limit state for joints that are always exposed and visible to view.

An earthquake also produces vertical ground accelerations however since the ground under two adjacent buildings is subject to the acceleration vertical displacement between the two is generally ignored.

7.3 Number of cycles

The number of cycles required by fire rating standards range from 500 to 100,000. The high cycle numbers tend to be more relevant to joints subject to small thermal movement cycles. Seismic events are infrequent and generally of short duration and the big one even more rare. NZS4203 requires a minimum duration of 15 seconds. Duration and number of cycles is shown in Tables 7.2 and 7.3 for a number of large earthquakes. The number of full cycles range between 7 and 27 therefore a value of 50 should be considered adequate. Figure 7.5 shows a displacement versus time graph for the X013PACOIMA earthquake used by Tjondro as summarised in table 7.3.

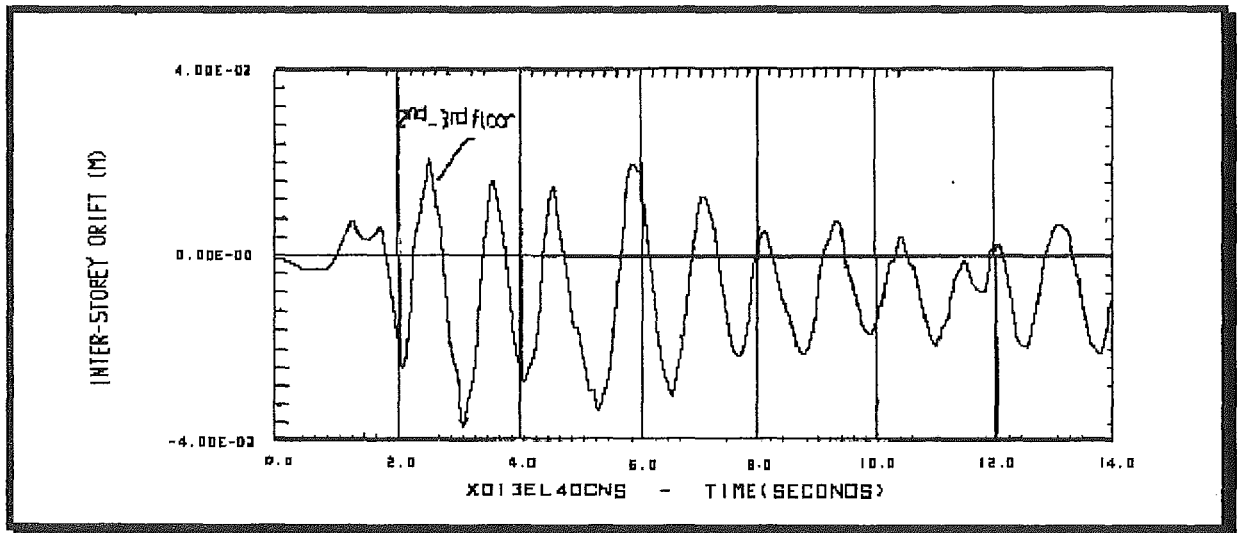


Figure 7.5 X013PACIOMA Earthquake

The earthquakes in Table 7.3 have also been used to model the deflection of steel frame buildings by various University of Canterbury Masters and PhD students and are included to give an indication of the variation in displacements over the short duration of the earthquake.

Researcher	Earthquake	No cycles	Dur- `ation (s)	Max/min top storey displacement (mm)	Building Height (m)
Sharpe PHD 1974					
	El Centro May 18 1940	10	10	±60mm / ±10	6
Tjondro ME 1988					
	X013EL40CN S	11	14.5	+120,-80 / +70,- 0	6
	X013PACOIM A	10	14.5	+250,-210 / +70,-0	6
	Y010EL40CN S	8	14	+200,-180 / +90,-70	12
	Y010PACIOM A	7	14.5	+450,-200 / +150,-50	12
	Z012PARKFI ELD	4	14	+500,-200 / +400,+300	18
	Z012PACIOM A	5	14	+700,-50 / +700,+500	18
Lin NZFSE 98					
	?	9	18	+250,-150 / +50,-0	?
Meggat etal NSNSEE 98					
	Pacioma	7	14		William Clayton Building Wellington 4 floor concrete constructi on
	Northridge	6	14	+/- 450/+/- 100	
	1.5 Elcentro	6	14	+/- 400/+/- 100	
Andriona PhD 89					
	Isodyn	8	14		
	Ruamoko	8	14		
McRae PhD 89					

	El Centro	7	14	+150,- 80/+120,+0	
	Parkfield	7	14	+400,- 100/+200,+100	
	Pacioma	7	14	+400,- 100/+200,-50	
	EQ/ART1	11	20	+180,- 170/+100,-40	

Table 7.3 Building movement under earthquakes

The range of movements for the earthquakes used for analysing buildings in table 7.3 are all less than half the ultimate limit state movement except for the William Clayton building where the movement is double the ultimate limit state.

The William Clayton building in Wellington has a base isolation system therefore whilst the building movement relative to other buildings or solid objects such as an adjacent retaining wall and motorway are high the inter-storey displacement would be expected to be low

7.4 Conclusion

In the absence of structural engineering calculations, designing for movement based on the ultimate limit state values would appear to meet the requirements of a lot of buildings. However straying beyond these limits without the advice of a structural engineer could have disastrous consequences as can be seen by the movement from the William Clayton Building.

8 KEY FEATURES OF A SEISMIC JOINT

8.1 Selecting and installing the correct joint

One of the fundamental requirements for a seismic joint to perform successfully is to select an appropriate joint and install it correctly. It sounds simple but in reality it involves a large number of people with varying technical abilities. The architect, structural engineer and fire engineer are involved in defining the movement, fire rating, external appearance durability and acoustic properties of the joint. The manufacturer must be able to convey how a joint meets these requirements and any limitations the joint may have particularly when it comes to variable on site conditions. The manufacturer must also be able to communicate to the installer how to install the joint correctly, any limitations that site conditions may impose and common solutions to some of these such as services passing through joints or variations in the static width of the joint. After the building is complete maintenance or fitout work may be carried out which could compromise the joint if the people involved do not understand the limitations or requirements of the joint.

A partial solution to this problem is to have a classification system for joints covering movement, fire rating, durability, surface finishes, and acoustic properties. Movement is the most difficult to comprehend so this would be ideally be illustrated with pictures and diagrams. The structural engineer could specify the structural part of the classification system, the fire engineer could specify the fire rating component and the Architect could specify surface finishes, construction constraints, acoustic and durability constraints. With this generic information the manufacturer is able to offer the correct products to meet the requirements.

Joints could then be installed with their classification system marked on them. This would ensure that everyone in the construction phase would be able to check the design requirements of the joints.

One method of ensuring the joints are installed correctly is to have accredited installers who are trained in the installation methods for the joints. The alternative is detailed instructions. Given the complex nature of joint movement and fire rating requirements successful installation by a builder or tradesman from installation instructions is likely to be prone to errors. Trained installers can also be trained in how to deal with variable on site conditions such as the gap being too large or services penetrating the joint.

Having dealt with how to get the correct joint designed, selected and installed we can begin to quantify and prioritise the physical properties and performance of the joint.

8.2 Movement

Due to large movements that can occur and the cost of producing joints for large

movements the required magnitude is going always going to be a topic for debate. In New Zealand the minimum requirements in accordance with NZS 4302 is to meet the serviceability limit state for most buildings and the ultimate limit state for more critical buildings.

8.3 Smoke and fire rating

On the assumption that life safety is more important than property protection and in the early stages of fire smoke is the greatest killer then a joints smoke stopping ability should meet the highest standards. Possibly it would also have a higher movement criteria. The fire rating value of the joint should be equivalent to the rating given to the surrounding non-moving components.

8.4 Durability

Life expectancy is generally going to be in keeping with the rest of the building bearing in mind that most joints are inaccessible for inspection or maintenance.

8.5 Testing

Fire testing of joints is an expensive process. Testing a simple straight line of joint is the lowest cost test however most joints have changes in direction, splices and joints in them which need to be considered. Also after an earthquake the joint may not be in the neutral installed position due to building deformation.

9 CODES STANDARDS AND REGULATIONS

9.1 Literature Survey

The literature search was carried out using a number of search databases. The most useful being the NIST Firedoc database which is accessible via the Internet. The url for this is <http://www.bfrl.nist.gov/top/search.html>. Canterbury University library department also carried out searches using key words. General searches were carried out using the common Internet search engines such as excite, webcrawler and lycos on the key words of seismic joints, fire rating, fire rated seismic joints. This generally led to companies selling fire rated products.

The literature searches revealed little information directly on the subject of fire rated seismic joints. The majority of information is contained in draft standards, which are summarised below.

Most literature is devoted to fire rating of gaps in fire rated barriers. Gustaferro 1975 covers fire tests between precast concrete panels, O'Hara 1994 covers through joint penetration systems i.e. pipes and cables passing through fire rated walls and floors, Quigg 1998 covers fire rating of joints in gypsum board walls, Richardson 1990 also covers this subject, Smith 1997 covers fire rating of joints and through penetrations in heritage buildings, Botting and Buchanan 1998 summarises work on fire rated joints and Botting 1998 covers spread of fire after earthquakes.

Nicholas 1995 who summarises many draft standards on Fire rated seismic joints and their progress carried out the most significant work.

9.2 Draft and Current codes

The following is a review of a sample of codes from around the world relating to fire rating of seismic joints and design movement. Whilst not exhaustive it provides sufficient information to determine the salient features of a standard.

UL 2079 2nd ed Jan 1997 Tests for Fire Resistance of Building Systems

This standard is produced by the Underwriters Laboratories Inc covers floor joints, wall joints, splices, the wall to floor interface and wall to ceiling interface. ASTM 1399 is referred to for movement.

The length of the test assemblies is 914 mm if the length of the joint relative to width is 10 times greater, otherwise the length is 2.7m. Distance of the joint from the furnace is 300mm maximum. Splices are 305mm minimum from the furnace wall and 914mm between splices. Joints are tested at their maximum width.

Joints are to have a minimum of 20 movement cycles. Where required conditioning of the joint is to take place it is at 23 °C and 50% relative humidity until the joint reaches equilibrium moisture content.

The standard time temperature curve is used for the furnace test. Details are given on thermocouple locations. Pressures are not to fall below 2.5 Pa. Failure is defined as either an integrity failure (using cotton pads which must not ignite during a 30 second period of exposure to any cracks) or temperature failure (where the temperature of unexposed surface is not to exceed 181⁰C).

There is an optional hose stream test which can be conducted within 10 minutes of completion of the test.

ASTM E 1399-91 Standard Test Method for Cyclic Movement and Measuring the Maximum and Minimum Joint Widths of Architectural Systems

This standard as the name implies covers cyclic movement of Architectural Joints. It requires joints to be cycled through their maximum and minimum joint widths for 5000 cycles at a rate of 30 rpm.

The rationale for the movement is based on an architectural design life of 50 years and 50 full cycles per year plus a 100% safety factor to cover smaller movements that occur. This number of cycles is more aligned to movement due to thermal expansion and contraction rather than seismic movement.

It also covers reporting methods and design of the cycling machine.

ISO TC92/SC2/WG6 N94 Sept 1990 Sealed Penetrations of Fire Resistant Separating Elements

This is a draft document that covers static joints and joints that are subject to thermal movement. The fire test method used is ISO 834 along with its integrity and insulation failure criteria.

Integrity failure occurs when continuous flaming is observed in excess of 10 seconds duration. Insulation failure occurs at 139 °C on the unexposed face at a single point. Insulation failure is not required for joints less than 12 mm wide.

Furnace pressures are to be 10 ± 2Pa at a height of 1m below the notional soffit of the test specimen.

Specimen shall have a length to width ratio of 5:1. A diagram shows a nominal length of 1m. Movement shall be at 45 degrees to the gap face, at a rate of 1 cycle per 30 minutes. The increase in width is to be 5% of the original gap width. No minimum number of cycles is given.

CEN Document N579 BSI Fire Resistance tests on service installations Oct 1993

This is currently being revised along with ISO TC92/SC2/WG6 N94 to become a uniform standard.

ISO TC92/SC2/WG6 N127 Sept 1992 Sealed Penetrations of Fire Resistant Separating Elements

This standard covers the penetration of pipes and cables through fire rated walls and floors.

AS1530.4 Fire Resistance Tests of Elements of Building Construction

This standard covers fire resistance tests for walls, partitions, floors, roofs, columns, beams, girders, trusses, door sets, glazing, air ducts and elements penetrated by services. It is stated as being close to ISO 843 fire tests and uses the standard time temperature curve.

The criteria for integrity failure is the development of cracks or openings which flames or hot gasses can pass through. Insulation failure occurs when the average thermocouple temperature rises more than 140K above the initial temperature or the spot temperature exceeds 180K above the initial temperature. The test pressure is 8Pa above ambient.

AS 4072.1 - 1992 Components for protection of openings in fire resistant separating elements

This standard covers methods of testing sealing systems around penetrations through fire rated building elements such as pipes, cables and ducts and also covers control joints between building elements. It uses AS 1530.4 as a basis for the tests.

Movement tests cover parallel movement between the faces. Three cycle regimes are used firstly an agreed number of 24 hour cycle tests, then 10,000 cycles at 60 s per cycle, then maximum compression for 7 days followed by gradual expansion to maximum extension over a 12 hour period. This system seems to be aimed at sealants.

Test specimen size is 140 mm for movement. And 1m by 1m with a 1m joint length for the fire test.

The standard covers different separating elements i.e. dry wall, concrete, masonry.

NZS 4203 1992 Code of practice for general structural design and design loadings for buildings

NZS 4203 covers the design loading for buildings including seismic loads. It provides a design criteria for maximum inter-storey deflection of buildings under specified magnitudes of earthquakes. It has two loading regimes: the serviceability limit state and ultimate limit state.

The serviceability limit state is defined as "the deflections of the structure shall not be such as to result in damage causing loss of function of the structure of its

parts". It is also defined as when the building becomes unfit for its intended use through deformation, vibrating response, degradation or other physical aspects.

The ultimate limit state is defined as "deflections that do not endanger life; cause loss of function of category I or II buildings, or category PI or PII parts; or cause damage to the contents of category III buildings; exceed building separation from site boundaries or between neighbouring buildings; cause loss of structural integrity".

Where:

Category I buildings are dedicated to life preservation

Category II buildings contain crowds

Category III buildings are publicly owned buildings which house contents of high value.

Category PI parts are parts which failure could lead to loss of life.

Category PII parts are parts for which continuing function is important.

The standard also gives values for maximum inter-story deflections as

0.02m/m for $h_n \leq 15\text{m}$

0.015 m/m for $h_n \geq 30\text{m}$

0.02 - 0.005(h_n-15)/15 for $15\text{m} \leq h_n \leq 30\text{m}$

where h_n is the building height

The standard states that the serviceability limit state forces to be used are 1/6 of the ultimate limit state forces so this can be extrapolated to mean that the deflections will also be 1/6 the limit state deflections.

The length of the input earthquake should contain at least 15 seconds of strong ground shaking duration of at least 5 times the fundamental period.

NZS 4541 Design of sprinkler systems for buildings

This standard covers the design of sprinkler systems. Section 403.14.1.2 covers movement. Where pipes cross structural separations i.e. seismic joints an allowance for relative movement of ± 160 mm per 4m of height of the structural separation or the building movement where known.

The ± 160 mm is the maximum ultimate limit state movement assuming structures on either side of the joint have the same movement.

The standard should clarify the option of designing for the actual building movement by stating that the movement should be the ultimate limit state movement.

NZS 4219 Specifications for seismic resistance for engineering systems in buildings

This standard covers the design of supports and bracing for building services equipment in buildings such as pipes, ducts, water tanks and other items of plant.

With regards to building movement it specifies a design criteria for inter-storey deflection of 1% of the inter-storey height. This equates to $\pm 40\text{mm}$ for 4m of building height which is half the maximum ultimate limit state value.

The standard refers to an outdated version of NZS 4203 as the reference for loadings therefore should be treated with caution.

9.3 Acoustics Moisture and Durability

Acoustics

This is covered by NZBC Clause G6 Airborne and Impact Sound. The performance criteria states that the sound transmission class (STC) of walls, floor and ceilings shall be no less than 55. The impact insulation class of floor shall be no less than 55.

Verification methods for airborne sound are ASTM 336 and ASTM E 413. Impact sound insulation is covered by ISO 140: Part VII and ASTM E 989.

Moisture

NZBC E2 covers moisture. The performance criteria state that walls, floors, roofs shall prevent the penetration of water that could cause undue dampness or damage to building elements. Excess moisture present at completion of construction shall be capable of being dissipated without permanent damage to building elements.

There are no verification methods to confirm compliance, only an acceptable solution.

Durability

This is covered by NZBC clause B2 durability. It requires a life of 50 years for elements which provide structural stability or to which access is difficult. For elements that have ease of access but are difficult to replace the required life is 15 years and for elements for which there is ready access the required life is 5 years.

Verification is by proof of performance in use. This may be a successful service history that is site specific. Laboratory tests may be used if they are relevant to the particular case. No specific test methods are given.

9.4 New Zealand Regulatory Environment

In December 1991 the Building Act was passed into law repealing a number of

earlier acts. It required the issue of the New Zealand Building Regulations (1992) and New Zealand Building Code. The New Zealand building code makes a departure from the previous NZS1900 in that it is a performance based code as opposed to a prescriptive code. Compliance with the code can be achieved by demonstrating that a design meets the performance based objectives or by compliance with an approved prescriptive acceptable solution.

Fire related aspects are covered by clauses C2, C3, C4 and appendices. Currently Australian and British Standards are referenced for compliance with fire rating requirements specified in the acceptable solutions.

The Building Industry Authority (BIA) is responsible for publishing the acceptable solutions.

10 CURRENT CODES VS KEY FEATURES

10.1 Collection and communication of data

None of the codes address the problems associated with selecting and installing the correct joint.

10.2 Ease of installation

None of the codes suggest any recommended design practices to ensure that joints are simple to install correctly.

10.3 Adaptable to various site conditions

UL2079 covers the splices and joins in joints.

None of the standards cover bends, changes in direction or complicating factors such as services passing through a joint.

10.4 Smoke/ fire rating

A lot of emphasis has been placed on the fire test, which is where there is a vast body of knowledge and experience. Time temperature curves are specified and criteria for structural stability, integrity and insulation are defined.

None of the standards cover the transfer of smoke in the early stages of a fire when temperatures are low.

There is plenty of literature on the design and testing methodology for furnaces.

10.5 Movement

Movement is covered with variable success. ASTM 1339-91 and AS4072.1 1991 talk about cycles more relevant to thermal than seismic movements. ISO TC92/SC2/WG6 N94 Sept 1990 attempts to cover movement in more than one plane by requiring the movement to be at 45° to the joint face. None of the standards address the issue of the magnitude of the movement.

ASTM 1339-91 covers the design of machines for testing for movement.

10.6 Durability

Durability and acoustic performance is covered by standards not specifically associated with seismic joints.

11 RECOMMENDED SEISMIC JOINT BEST PRACTICE

11.1 Overview

There are numerous pitfalls in the lifecycle of a fire rated seismic joint that may prevent it from performing its intended function of preventing the spread of fire. This section takes the problems identified in previous chapters to provide a set of recommended best practices covering the lifecycle of a fire rated seismic joint. The life cycle is divided into these distinct phases.

- Design
- Manufacturing and testing
- Selection
- Specification
- Installation
- Maintenance

A large number of people of varying technical abilities are involved during the lifecycle of the joint therefore a strong theme running through all phases of the lifecycle is the ability to communicate the performance requirements of the joint.

11.2 Design

Key design considerations include the following:

11.2.1 Fire rating

Fire ratings in New Zealand range from 15 minutes to 4 hours with the most common requirements being between 30 to 120 minutes. The fire rating requirements for specific building elements is generally specified in a fire report prepared by a Fire Safety Engineer. Figure 11.1 shows the fire rated element of a wall joint that requires a fire rating to be specified for it.

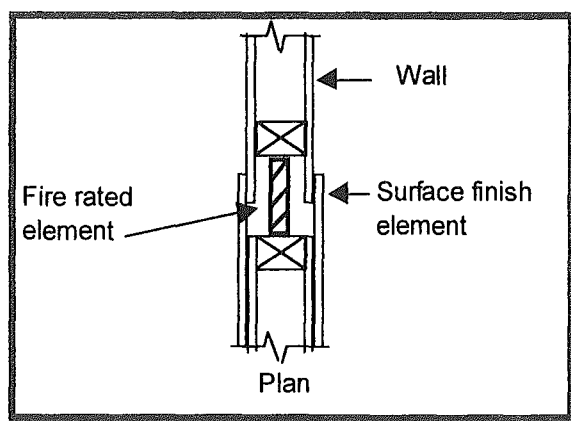


Figure 11.1 Seismic joint fire rated element

11.2.2 Smoke seals

It is well documented that smoke is a major killer of people in a fire therefore adequate smoke sealing provisions is essential. Figure 11.2 shows how a smoke seal is incorporated into a floor joint.

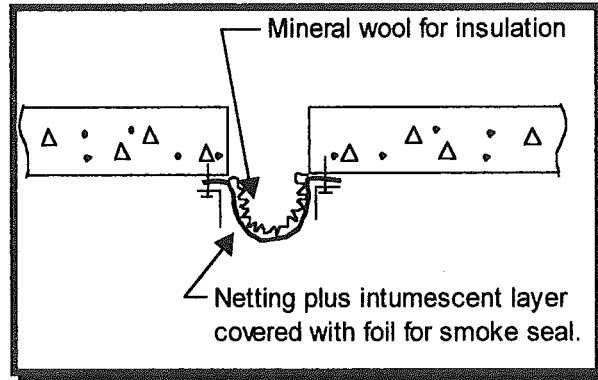


Figure 11.2 Seismic joint smoke seal

11.2.3 Jointing

Seismic joints are generally manufactured in fixed lengths then joined together on site to form a continuous strip. Figure 11.3 shows how a simple board type joint may not provide an adequate seal at the join if it is not installed carefully. A poor joint will let through smoke and fire.

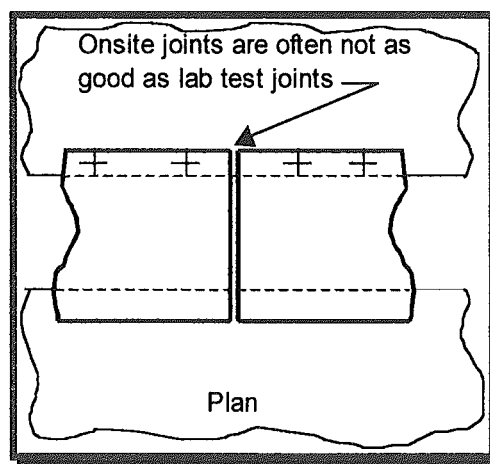


Figure 11.3 Seismic joint splice

11.2.4 Changes in direction

Frequently joints are required to have changes in direction. Joint designs require solutions for corners, bends and offsets. A change in direction of a joint may also be accompanied by a change in movement requirements.

Figure 11.4 shows a floor joint turning through 90°. If the building movement across the corridor is ± 100 mm and down the corridor ± 25 mm then the

required movement capability of the joint is quite different up the corridor and across the corridor.

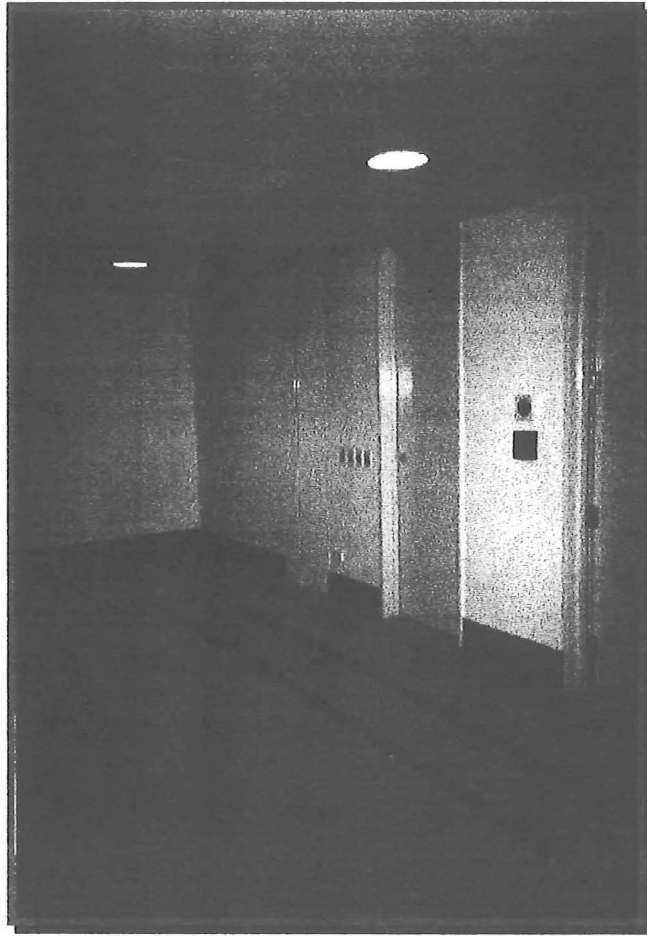


Figure 11.4 Seismic floor joint

11.2.5 Exposed surface

The exposed surface is not always part of the seismic joint design, for example a cover on a floor joint or a gypsum board wall covering a wall joint. The major risk of designing for joint movement less than the ultimate limit state movement is that the joint may fail due to excess movement and not be observed. The building may then be deemed fit for re-occupancy yet have concealed fire rated seismic joints that have failed due to excess movement.

If the exposed surface is designed to fail before the joint fails then there is a visual indication that the joint has failed and should be inspected. This increases certainty and allows designs for less movement. Some design ideas to demonstrate how this can be achieved are presented in section 11.2.9.

11.2.6 Installation

Installation should be as fool proof as possible and where possible with components that will only fit together in one way which is the correct way.

Part of the design process is preparation of installation instructions. Ideally they should be simple with numerous diagrams to illustrate installation and the range of movement the joint will be subjected to.

Joints with installation instructions integral to them either by being printed on, embossed or using stickers mean they are always available to the installer and any subsequent people carrying out repair or fitout work. Examples of stickers showing the performance criteria are given in section 11.5

Robustness of design is also necessary to take the bumps and knocks during the installation phase. Figure 11.5 shows a seismic joint having to content with construction rubbish.

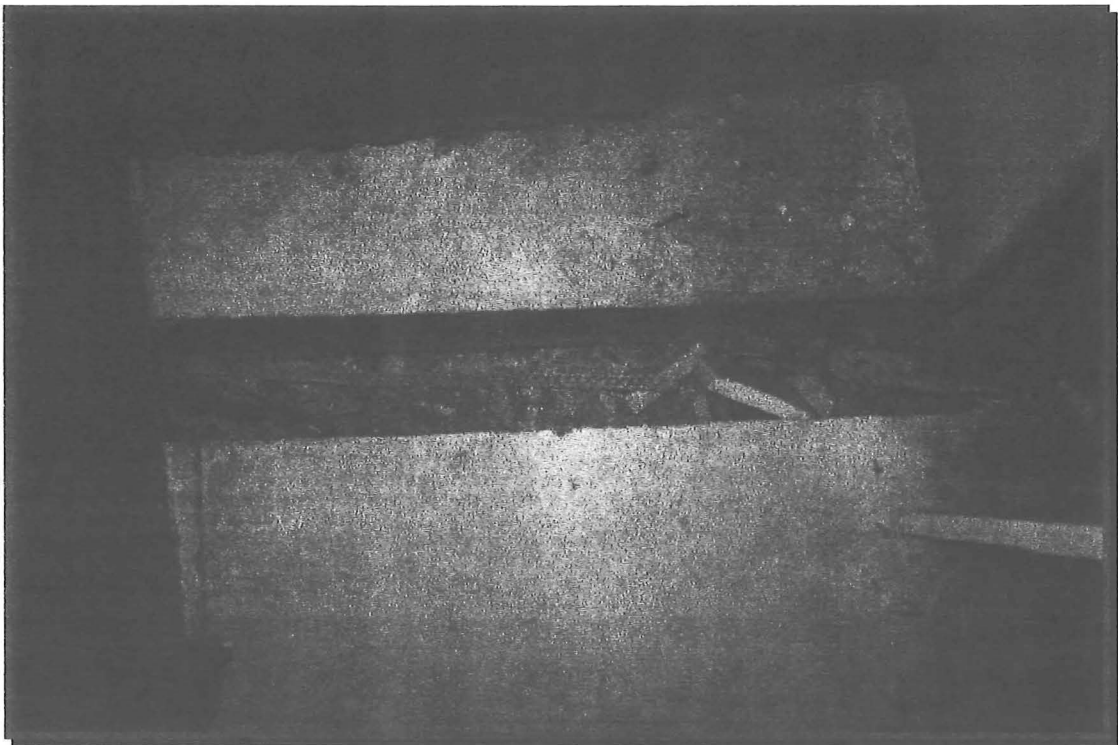


Figure 11.5 Seismic joint filled with construction rubbish

11.2.7 Durability

In New Zealand durability is covered by NZBC clause B2 durability. This requires a life of 50 years for elements which provide structural stability or to which access is difficult. For elements that have ease of access but are difficult to replace the required life is 15 years and for elements for which there is ready access the required life is 5 years.

Fire rated seismic joints will generally require a durability of 50 years.

Joints will be subject to a number of environmental conditions such as:

- Water (even for internal joints as they may be subject to flooding from a burst water pipe).

- Vermin (mineral wool can make an ideal rodent nest).
- Sunlight if exposed to the outside.
- Temperature.

11.2.8 Range of movement

In New Zealand NZS 4203 gives the upper bounds for movement. Generally vertical movement will be minimal. Horizontal movement will generally be in two directions.

Fire rated seismic joints most commonly occur in low rise buildings under 5 stories or where a podium is a separate structure to a tower. The other common location is in infill walls that need to be separated from the building structure. These will be subjected to the inter-storey deflection that is the same as the deflection for a single story building and reduces slightly as a building gets higher.

The other significant distinction for movement is whether the building is classified as a category I or II building. These are buildings dedicated to the preservation of life or containing crowds. NZS 4203 requires these building to remain operational after being subject to ultimate limit state movement. Whilst not explicitly stated in the standard the author believes that fire rated seismic joints in these buildings would also have to remain functional.

Other buildings are only required to remain operational after being subject to the serviceability limit state movement. This runs the risk of a joint remaining in service after being damaged in a significant earthquake since they are generally concealed. To mitigate this any material that covers the fire and smoke rating component should be designed to fail and expose the joint prior to the fire or smoke rating component failing.

Note also that the range of movements are the upper bounds of movement and the structural design may be such that the movement is less. Table 11.1 gives maximum horizontal deflections for varying building heights under the serviceability and ultimate limit state design based on maximum inter-story deflections given in NZS 4203. The slab to slab height is taken as 3.5m. The movements are for a single building therefore they need to be doubled to get the deflection between two buildings. This movement can potentially occur in two perpendicular directions.

Floor	Building Height m	Ultimate Inter-storey deflection (mm)	Ultimate limit state deflection (mm)	Serviceability Inter-storey deflection (mm)	Serviceability limit state deflection (mm)
1	3.5	70	70	12	12
2	7	70	140	12	23
3	10.5	70	210	12	35
4	14	70	280	12	47
5	17.5	67	348	11	58

Table 11.1

11.2.9 Verification of seismic joint after an earthquake

One of the big questions regarding the use of the serviceability movement limits for seismic joints is what happens when the earthquake movement larger than have been designed for. Joints are often hidden from view so it may not be observed that they have failed.

Designing joints so that in an earthquake the outer covering fails before the fire rated element fails is one way around this. Once the joint is exposed it should be visually obvious that it has failed or have labels describing what to look for. This could easily be the installation instructions or labelling of performance criteria.

Ideas for designing the outer covering to fail are:

If movement exceeds the allowable movement the covers over the joint are designed to pop off and expose the joint as shown in Figure 11.6. A similar strategy could be applied for movement in a lateral direction.

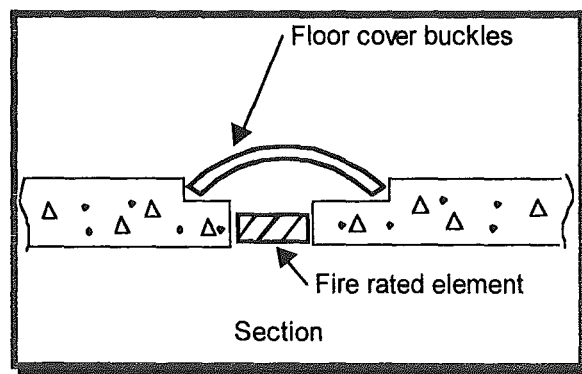


Figure 11.6 Floor joint cover buckles

When the joint is concealed in a wall cavity the walls could be linked so that they deform under excess movement as shown in figure 11.8.

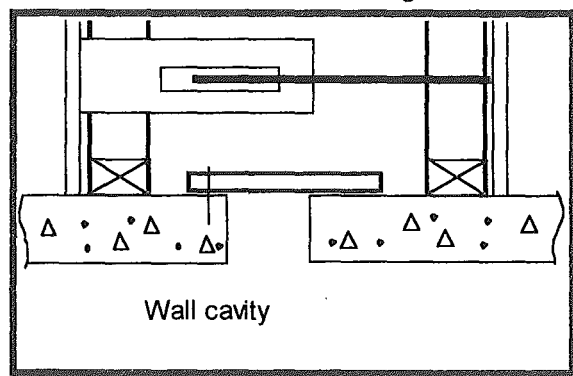


Figure 11.8 Floor joint concealed in wall cavity

In figure 11.9 gypsum board walls are designed for less movement than the fire

rated element so they fail earlier. In this example they will fail after very small amounts of lateral movement.

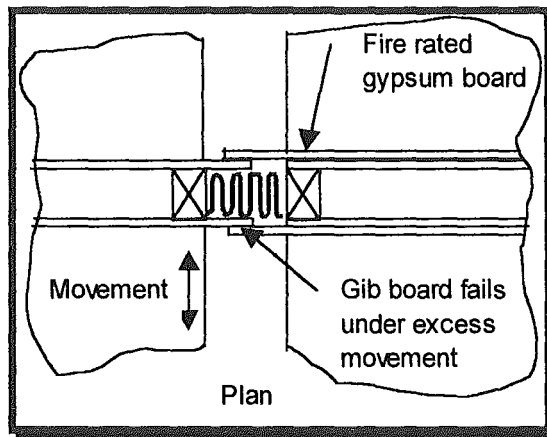


Figure 11.9 Gypsum board wall joint cover

Figure 11.10 shows an actual installation where the gypsum board walls are designed for approximately 20mm of compression.

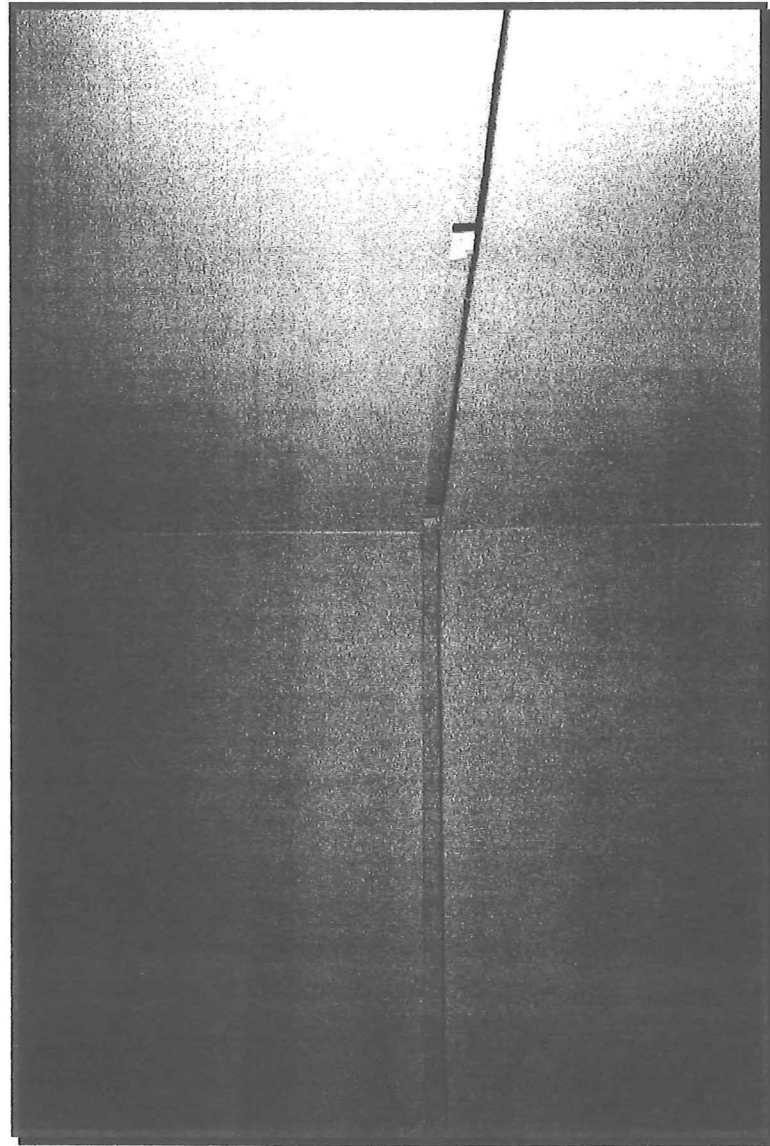


Figure 11.10 Gypsum board wall joint cover

11.3 Testing

Table 11.2 summarises the salient features of a number of standards with regards to testing of fire rated seismic joints. The column headed J D Nicholas conservative criteria is based on his review of the state of standards as of 1995 and his proposed conservative standard.

The two NZBC columns list relevant information from Australian and British standards that are already referred to in the New Zealand Building Code Acceptable Solutions section C appendix E 7.0. The last column in the table is a proposed testing regime by the author for New Zealand based on the approved Australian and New Zealand Standards with additional requirements adapted from other standards to make up the short fall. Factors that were considered for the proposed test regime are:

Joint Length

Standards reviewed have joint lengths ranging from 1 m to 2.7 m for walls and 3.7m for floors. Factors to be considered include the heat loss from the end of the joint at the edges of the furnace, spacing of splices and ability to place the joint under differential deflection.

Splices

Splices can be either factory or site made. From observations of numerous seismic joints in buildings site splices are the most likely area for something to be installed incorrectly.

Fire Tests

Each standard varies in the detail specified for the fire test. They all use the ASTM E119 standard time temperature curve or the ISO 843 curve which are very similar. The BS standard goes into the greatest detail for fire tests. The NZBC specifies both the Australian and British standards as being acceptable.

Pressure

Various standards give furnace pressures ranging from 2.5 Pa to 10 Pa. The higher pressures obviously give more conservative results. The AS and BS standards use pressures at the high end of the range.

Integrity

The definition of failure ranges from observing test cracks which hot gasses can pass through (AS) to flaming of cotton buds (UL and BS). The latter would appear more scientific.

Insulation

Two failure criteria are used: 181 °C single point temperature above the initial conditions and 140 °C average temperature rise above the initial temperature. These temperatures apply to the surface of the joint not exposed to the furnace. The more conservative criteria is to use both. This is used by both the Australian and British standards.

Test Under Load

Whilst the joint itself is unlikely to be a load bearing element, the supporting structure either side of the joint often is load bearing. If each side of the joint is loaded differently it may lead to the production of gaps in the fire rating, or the joint may be prone to failure in an earthquake.

Standard	UL 2079	IS TC92/SC2/ WG6 N94	J.D Nicholas conservati ve criteria	NZBC/ AS 1530.4 and AS 4072.1	NZBC/ BS 476 Pt 20	Proposed testing regime
Joint length	914mm min up to 2.7 m	5:1 ratio of width. 1m indicative	3.7 m floors 2.7m walls	1m		1m min
Splices	Yes. 300mm from furnace wall. 914 mm spacing	-	Factory and field splices	-	-	Factory and field splices. 300 mm from wall and ceiling of furnace.
Movement	Yes	Yes 45 ° to gap face. 5% of original gap width		AS 4072.1 test results only valid for movement less than tested		test, axial lateral and vertical dependant on application
No Cycles	20 cycles min. Also ASTM 1399 5000 cycles @ 30 rpm	1 cycle per 30 min	500 cycles @ 2cpm and cycled during fire test	AS 4072.1 10,000 @ 1rpm		20 for seismic, 5000 for thermal
Fire Test	Standard time temp	ISO 843		AS 1530.4 standard time temp	standard time temp	standard time temp
Pressure	2.5 Pa	10 ± 2Pa	20 Pa	AS 1530.4 8 Pa	8.5Pa/m height, 1m above neutral plane. Max 20 Pa	AS 1530.4 8Pa
Integrity failure	Cotton pads ignite after 30 s exposure	Continuous flaming observed for 10s		AS 1530.4 observation of cracks or openings which hot gasses or flames can pass.	Cotton pads flame or glow	Cotton pads ignite after 30s exposure
Insulation failure	181° C local temp above initial temp	139 ° C above average initial temp	181° C local and 139 ° C average above initial temp	AS1530.4 180° C local and 140 ° C average above initial temp	180° C local and 140 ° C average above initial temp	180° C local and 140 ° C average above initial temp
Test under	Yes if used	-	Yes differential	Yes if used in practice	-	Test for differential

load	in practice.		deflection	(AS 1530.4)		deflection
Other	Optional hose stream test	-	-	-	-	-

Table 11.2 Existing and proposed standards for testing joints

11.4 Selection

To assist architects and engineers to quickly calculate the movement required of a joint, select an appropriate joint and prepare a specification, a series of web pages have been produced.

This format has been chosen for its portability. Most personal computers have Internet web browsing programs such as Microsoft Internet Explorer or Netscape that are suitable for viewing the pages. This applies not only to computers with the popular Microsoft Windows operating systems but also Macintoshes and Unix based computers. The pages can either be viewed on a personal computer, on an intranet or on the internet.

The pages make use of the javascript language to dynamically generate pages in response to user input. The HTML and javascript code is included in Appendix C

The pages allow users to carry out four tasks

- Enter a building height and number of floors to produce a table of ultimate and serviceability limit state movement for each floor level in accordance with NZS 4203.
- Answer a series of questions to produce a custom specification for a particular seismic joint.
- View seismic joints in motion by selecting a joint type and entering a joint initial gap and movement in the x, y and z axis. The joint movement changes dynamically as values are changed.
- View a slide show of various joint types and their problem areas.

Screen shots of the pages are shown in Figures 11.11 to 11.15.

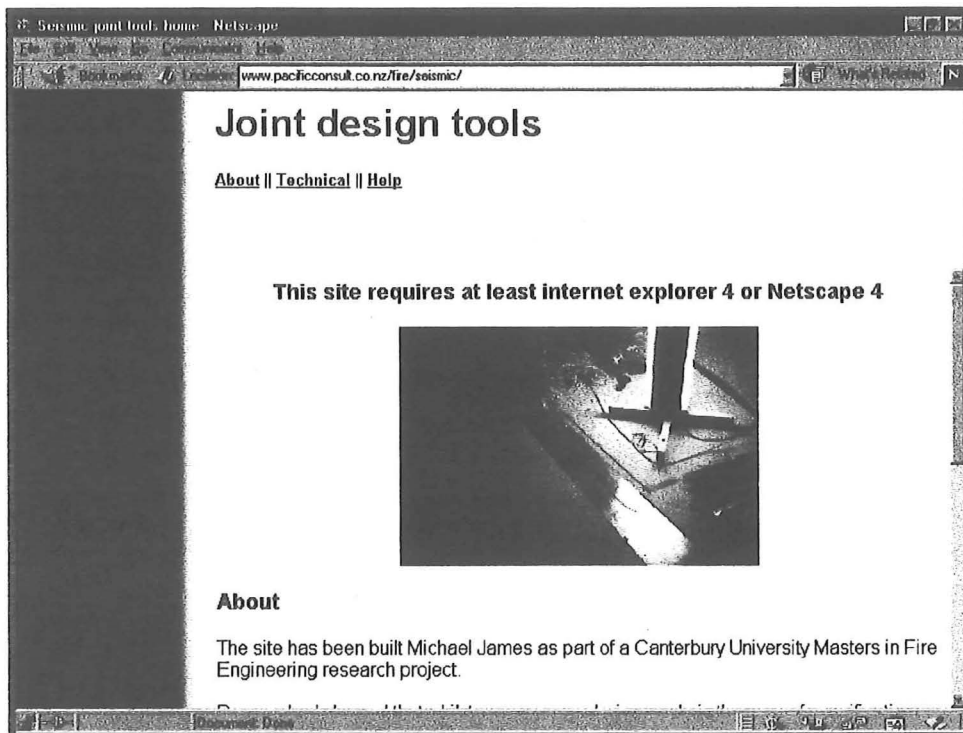


Figure 11.11 Home page

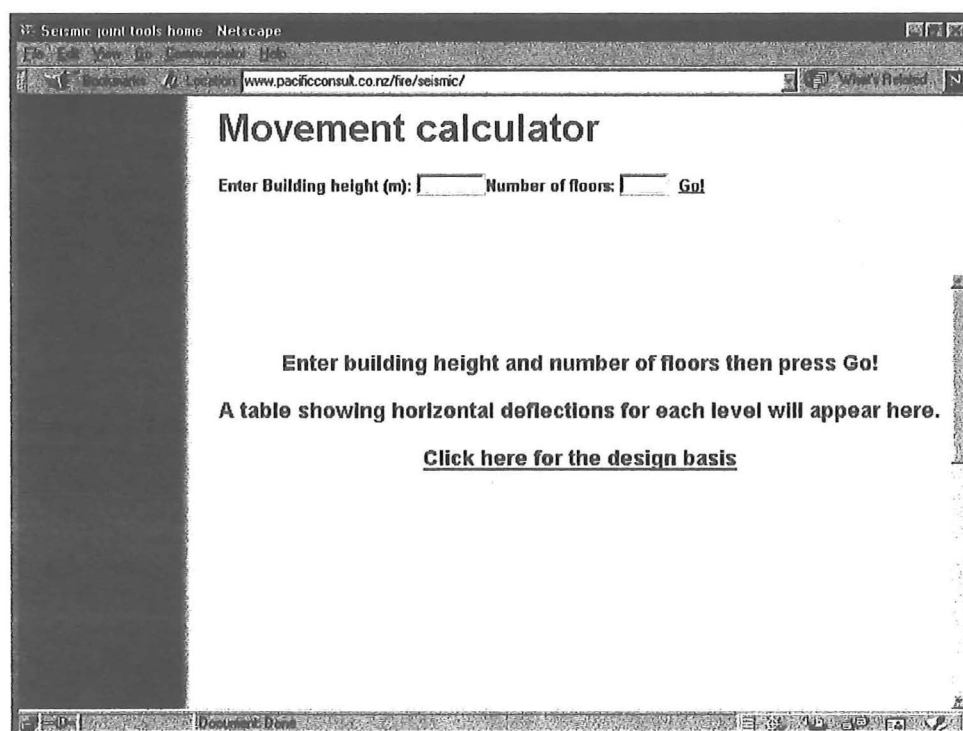


Figure 11.12 Movement Calculator

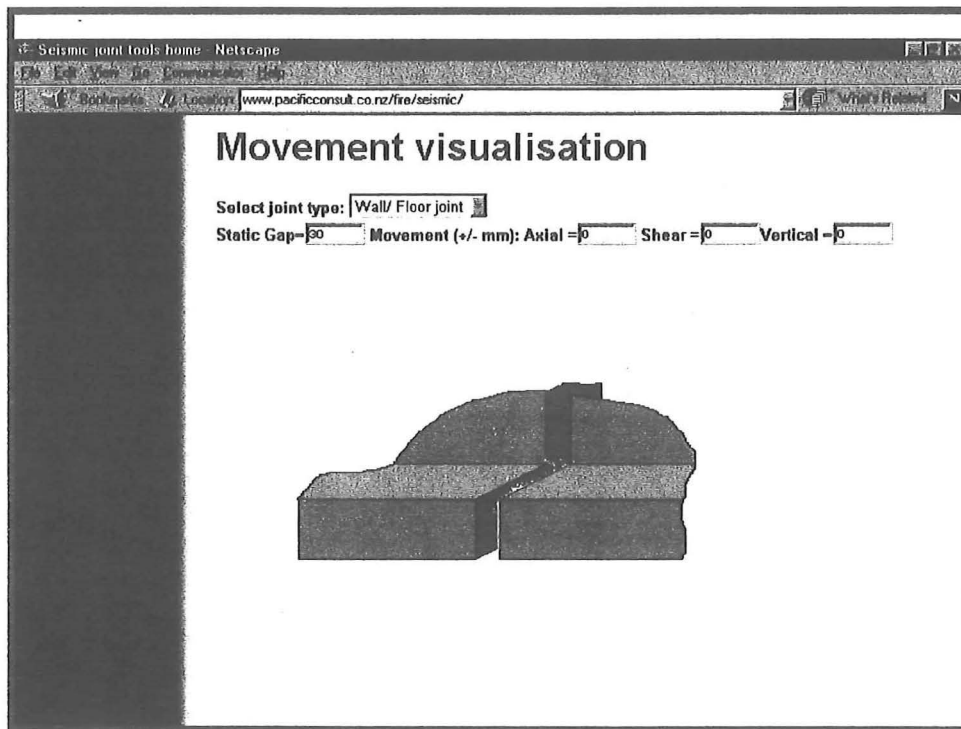


Figure 11.13 Movement Visualisation

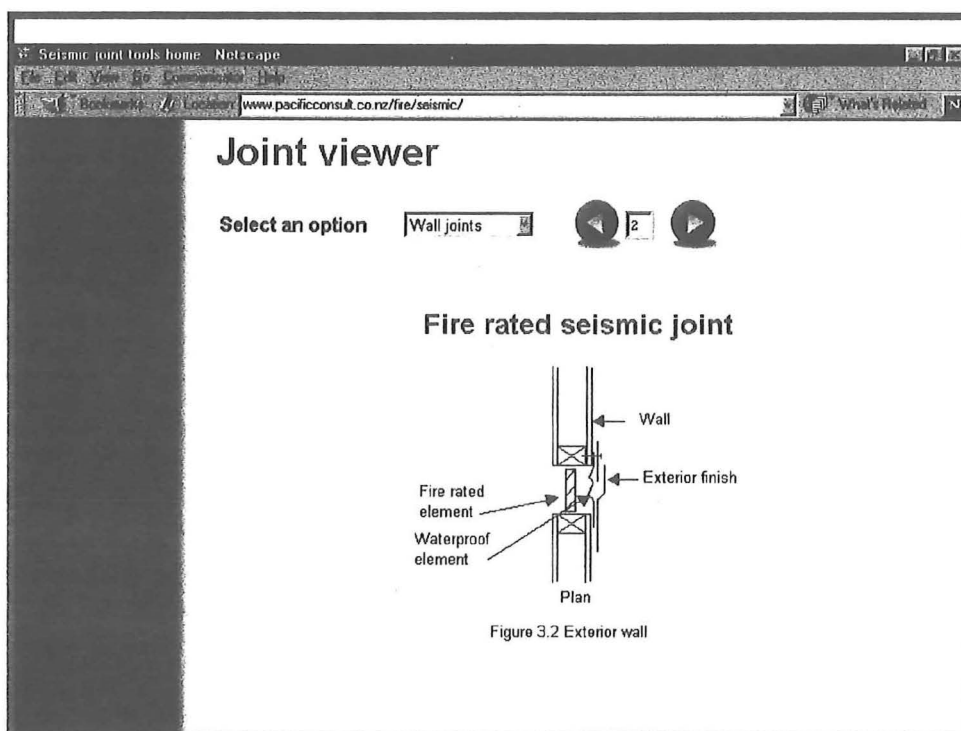


Figure 11.14 Joint slide show

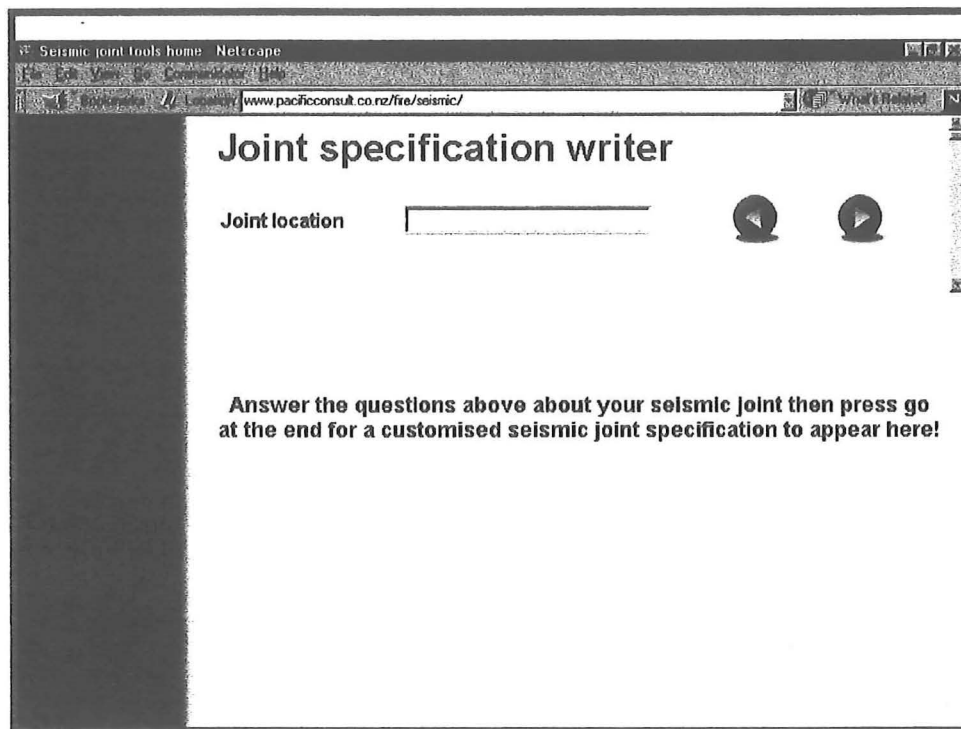
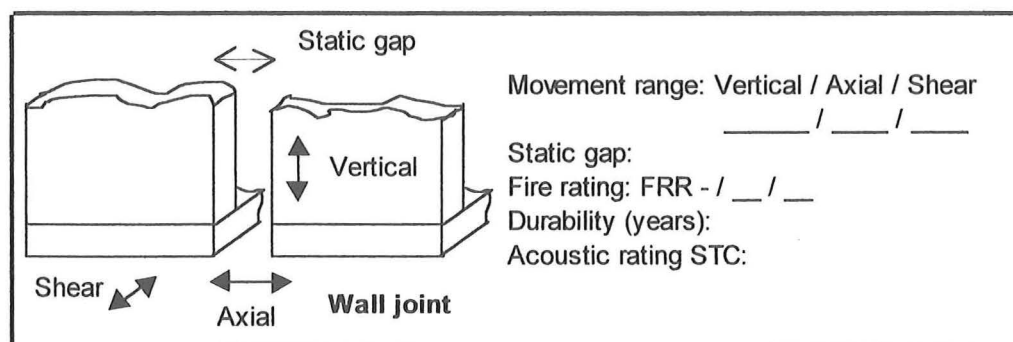


Figure 11.15 Specification writer

11.5 Specification

In these days of performance specification writing as opposed to selecting specific products it is important to specify the performance requirements either on the drawings or in the specification or a combination of these. Movement is best displayed on the structural and architectural drawings.

Communication of the movement performance criteria is best conveyed through pictures. Figure 11.16 shows a labelling system that can be applied to drawings. It can also be used as a labelling system for installed joints to indicate the performance criteria for the joint.



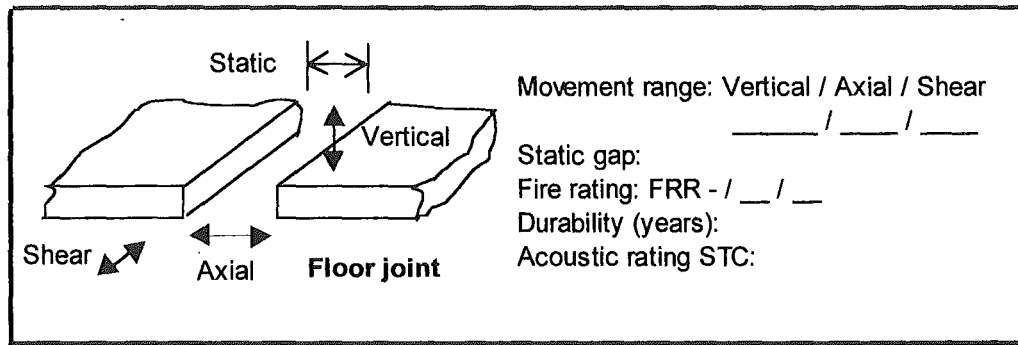
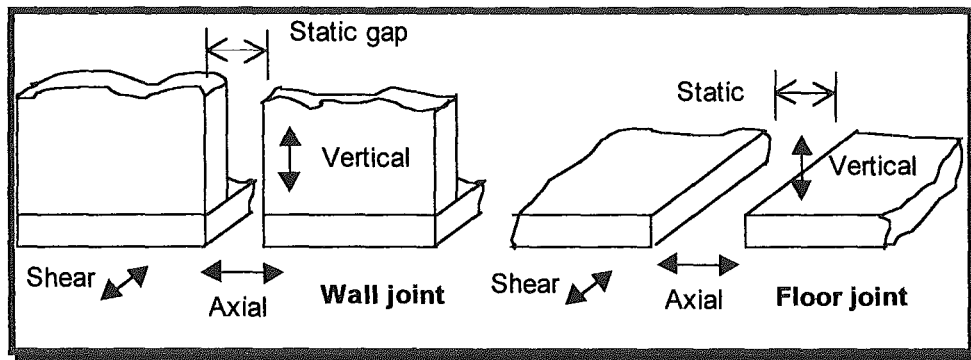


Figure 11.16 Floor and Wall joint labels

The following is a generic datasheet for describing the performance requirements of a seismic joint, which can be included in a specification.

Seismic Joint Specification Sheet



Joint location:

Joint type: Wall | Floor

Movement range

Vertical: ± 5 mm, 10, 15, 25, 50, 75, 100, 150, 200, 250

Axial: ± 5 mm, 10, 15, 25, 50, 75, 100, 150, 200, 250

Shear: ± 5 mm, 10, 15, 25, 50, 75, 100, 150, 200, 250

Static gap: ± 5 mm, 10, 15, 25, 50, 75, 100, 150, 200, 250

Base wall construction: conc. / timber stud / Metal stud / Other

Base floor construction: conc. / timber / other

Fire rating: FRR ____ / ____ / ____

Joint exterior: Concealed / exposed

Exposed surface material 1.

2.

Durability (years) : 10, 20, 50, 75, 100

Acoustic requirements: STC 20, 30, 40, 50, 60

Other specific requirements:

.....

11.6 Installation

One method of ensuring that the joints are installed correctly is to have accredited installers who are trained in the installation methods for the joints. The alternative is detailed instructions. Given the complex nature of joint movement and fire rating requirements, successful installation by a builder or tradesman from installation instructions is likely to be prone to errors. Trained installers can also be trained in how to deal with variable on site conditions such as the gap being too large or services penetrating the joint.

11.7 Maintenance

Once a building has been finished and the engineer and Architects involvement completed there is the potential for seismic joints to be altered or changed without any understanding of the joint function. Clearly labelling of joints as outlined in a previous section helps to mitigate this problem.

An example of a labelling system for fire rated components is the label placed on fire doors. In New Zealand fire doors are required to be labelled with the name of the manufacturer their fire rating, and date of manufacture. This greatly assists future engineers and non-technical staff to ascertain the intended performance of an existing fire door

12 CONCLUSIONS

Seismic joints are an important part of the fire safety in buildings in earthquake prone locations.

Importance

A fire rated seismic joint can be required to perform its smoke and fire stopping function in three scenarios

1. During a building fire with no earthquake having been present.
2. During a fire immediately after an earthquake.
3. During a fire sometime after an earthquake when the building is deemed safe to occupy.

During a fire when no earthquake has been present an active fire suppression system such as a sprinkler system is more important than a fire rated seismic joint.

Immediately after an earthquake the likelihood of active fire suppression systems being operational is low therefore passive fire protection features become very important.

Fire rated seismic joints are often concealed from view therefore a building may be put back into operation after a significant earthquake with failed fire rated seismic joints. In buildings without active fire suppression systems, passive fire prevention features such as fire rated seismic joints are very important for life and property protection.

Smoke

In terms of life safety the ability of the seismic joint to stop the passage of smoke is the most important feature in the early stages of a fire when people are escaping. The Las Vegas, MGM Grand fire of 1980 is an example of inadequate smoke stopping leading to numerous deaths occurring many floors away from the seat of the fire.

Movement

New Zealand Standard NZS 4203 provides maximum seismic movement criteria for buildings. It provides two states of movement, the ultimate limit state and serviceability limit state. The serviceability limit state movement is 1/6 of the ultimate limit state movement.

Buildings must remain operational after being subject to the ultimate limit state movement if they are used for the preservation of human life or contain crowds. Other buildings need only comply with the serviceability limit state movement.

Fire rated seismic joints are often concealed therefore it is hazardous to design them for a movement range less than the ultimate limit state unless there is a

means of checking that they are still operational after a significant earthquake. This can partially be achieved by designing covering materials over seismic joints to fail before the seismic joint fails due to excessive movement.

Testing

Standards and codes of practice for the design, selection, testing and installation of seismic joints are in their infancy.

Most standards have a lot of detail on the actual fire test. Additional features that need to be covered are the number of movement cycles for tests relative to earthquake movement rather than thermal movement, movement in more than one plane or direction, and passage of smoke in the early stages of a fire.

Durability

Durability of seismic joints is covered by standards related to general building products. Attention needs to be given to the fact that joints are generally inaccessible therefore may not be checked or replaced after a major earthquake or fire.

Information

For the successful selection and installation of a joint the method of communicating the performance requirements of the joint can not be ignored. The most appropriate method for assisting this may be a classification system of joints using pictures and diagrams to illustrate the movement requirements. This classification system would be branded on the joint in a similar way as fire rated doors are identified so that anyone at a future point in time could determine what the joint was designed for.

Selection

The selection and specification of a seismic joint is generally carried out by the Architect with input from the structural engineer for movement, the fire engineer for fire rating, and the manufacturer for compatible products meeting the design criteria.

This is a complex process particularly when it comes to assessing the movement requirements. To assist in the process a set of internet based visual tools have been developed. These enable a preliminary assessment of movement requirements to be made and show how the movement will occur in a particular joint. These tools are available for viewing at <http://www.pacificconsult.co.nz/fire/seismic>.

Installation

During the installation phase there are many opportunities to install the joint incorrectly. These include

- inexperienced installers
- changes to the selected joint design
- changes to the gap the joint has to span
- construction damage by construction work being carried out by people other than the joint installers.

Later on after the building has been constructed the joint can be further damaged by people doing fitout or maintenance work on the building.

13 RECOMMENDATIONS

To raise the standard of seismic joint selection, testing and installation the two key recommendations are:

- That the testing criteria outlined in section 11.3 be used to form the basis of a test regime.
- That the seismic joint labels described in section 11.5 be applied when installing seismic joints.

To ascertain how current fire rated seismic joint installations may fare under earthquake and fire conditions:

- A selection of current joint designs should be tested for movement and fire rating against the proposed standard.

Serious consideration should be given to new joint designs for the ability to ascertain a joint's ability to perform its intended function after an earthquake. Designing the outer seismic joint cover to fail before the hidden fire rated element failed thereby exposing the fire rated element for inspection achieves this.

There is scope for further web-based development to assist in the selection and specification of seismic joints. Two are:

- Animation of actual manufacturer's or proprietary seismic joints to show how they perform.
- A seismic joint selector to select a generic seismic joint based on it's location and the range of movement it will encounter.

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APPENDIX A

SEISMIC JOINT IMPORTANCE ANALYSIS

Fire rated seismic joints

Impact assessment of joint failures occurring

before, immediately after, and long after an earthquake has occurred

Click on scenario below to go to the selected worksheet

Scenario 1 - No Earthquake

Building with no fire alarm or suppression system

Building with a manual fire alarm system

Building with an automatic smoke or heat detection system

Building with sprinklers

Scenario 2 - Immediately after an earthquake

Building with no fire alarm or suppression system

Building with a manual fire alarm system

Building with an automatic smoke or heat detection system

Building with sprinklers

Scenario 3 - Some time after an earthquake

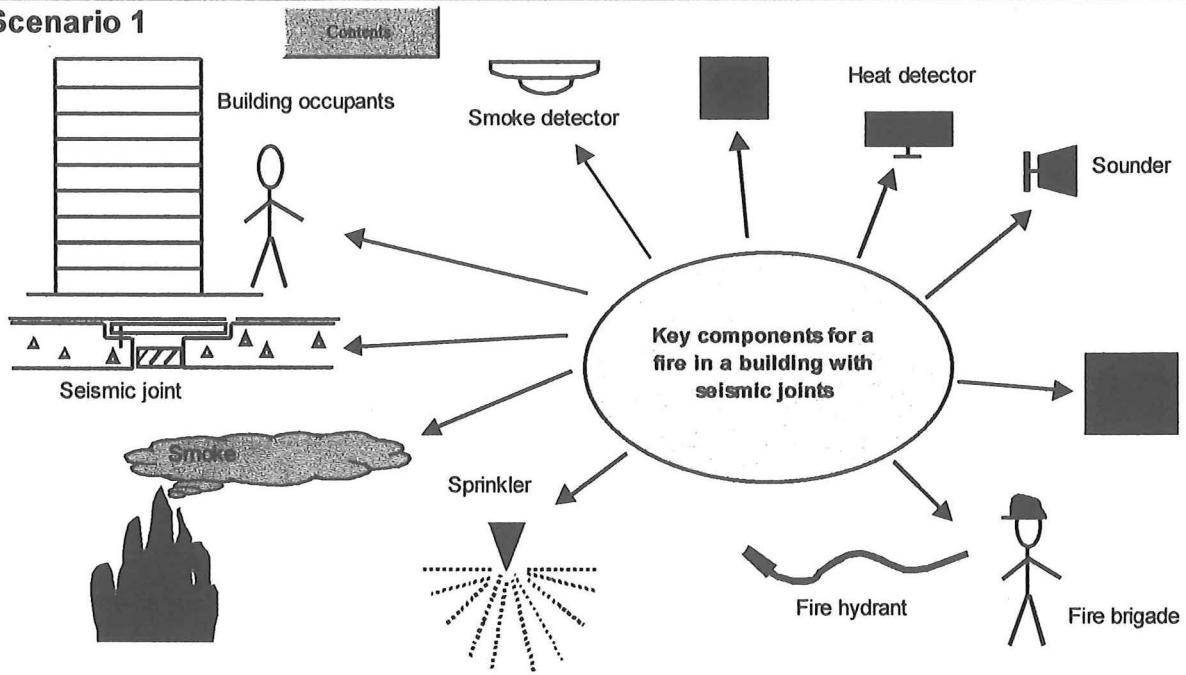
Building with no fire alarm or suppression system

Building with a manual fire alarm system

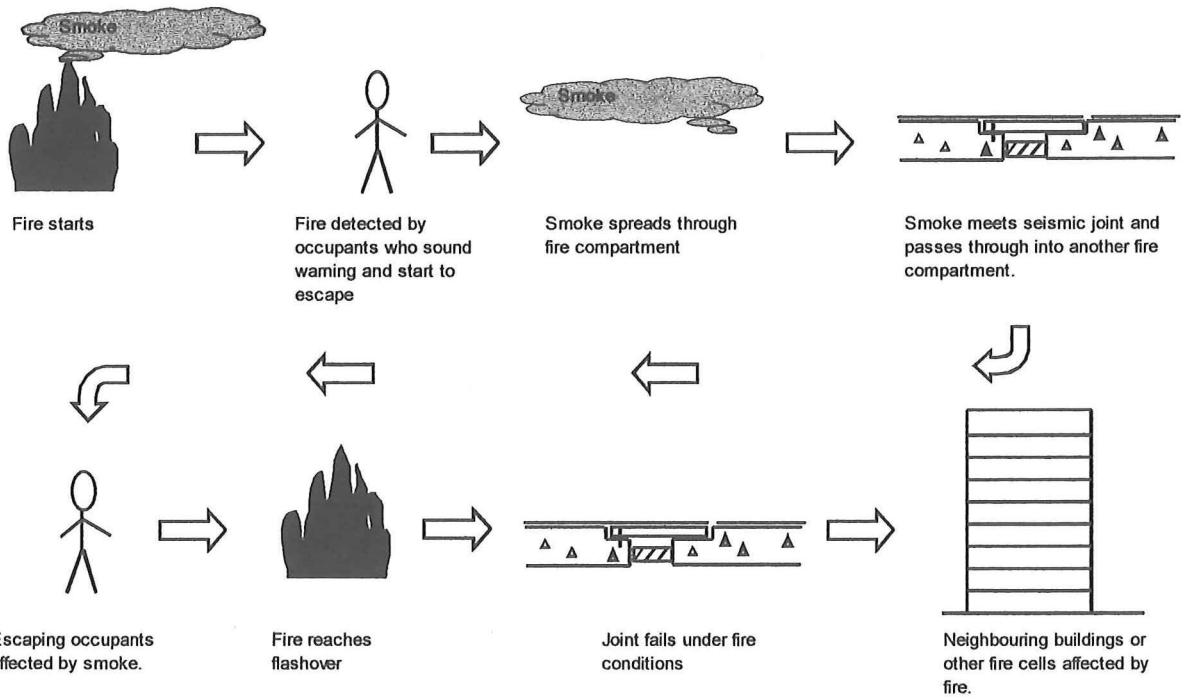
Building with an automatic smoke or heat detection system

Building with sprinklers

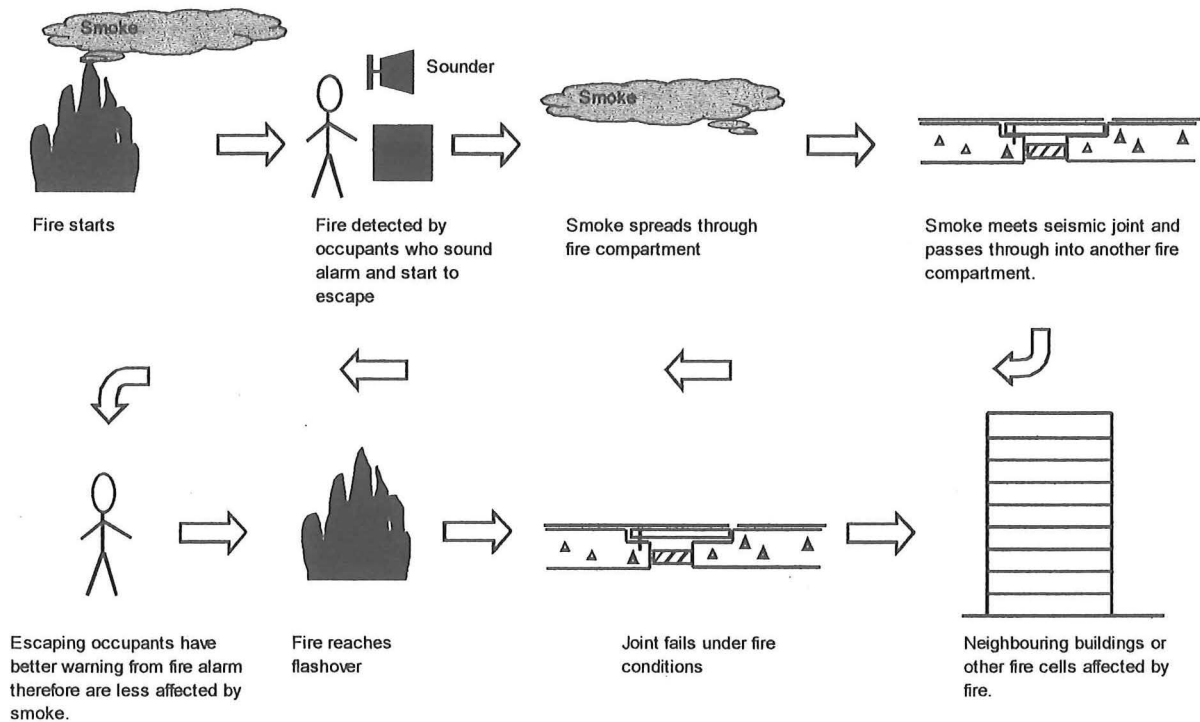
Scenario 1



Scenario 1 - No Earthquake Building with no fire alarm or suppression system



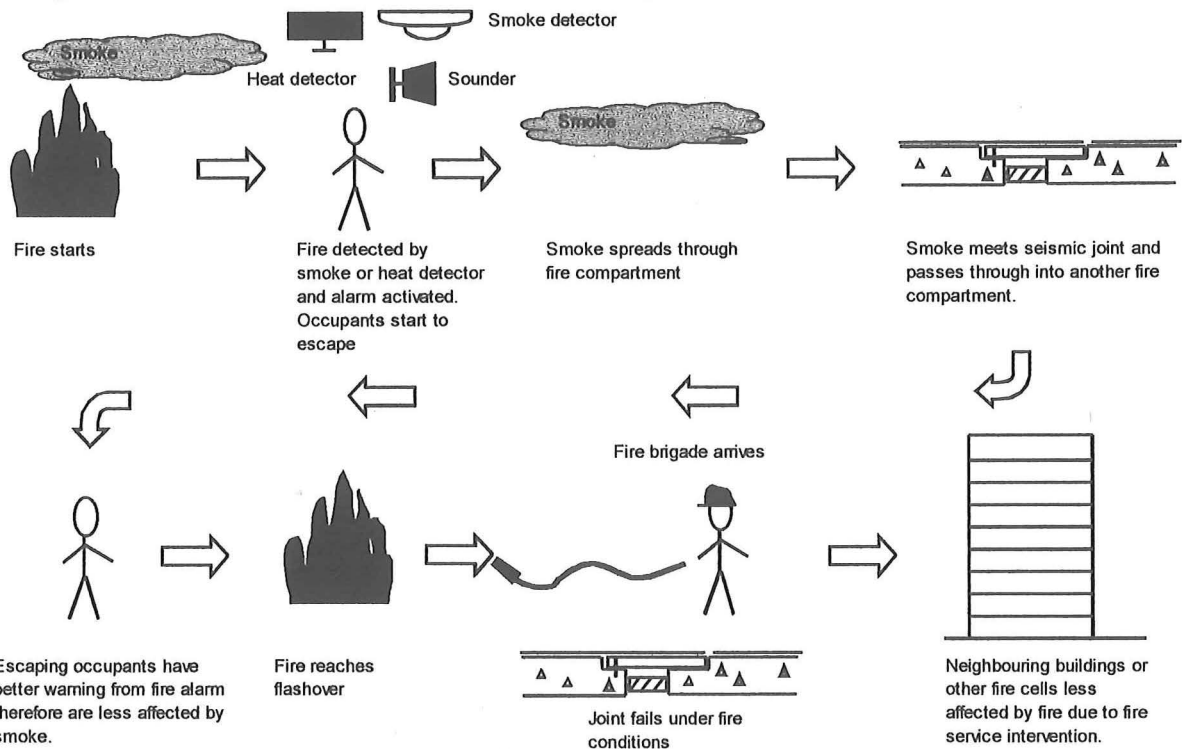
Scenario 1 - No Earthquake Building with a manual fire alarm system



Scenario 1 - No Earthquake

Building with an automatic smoke or heat detection system

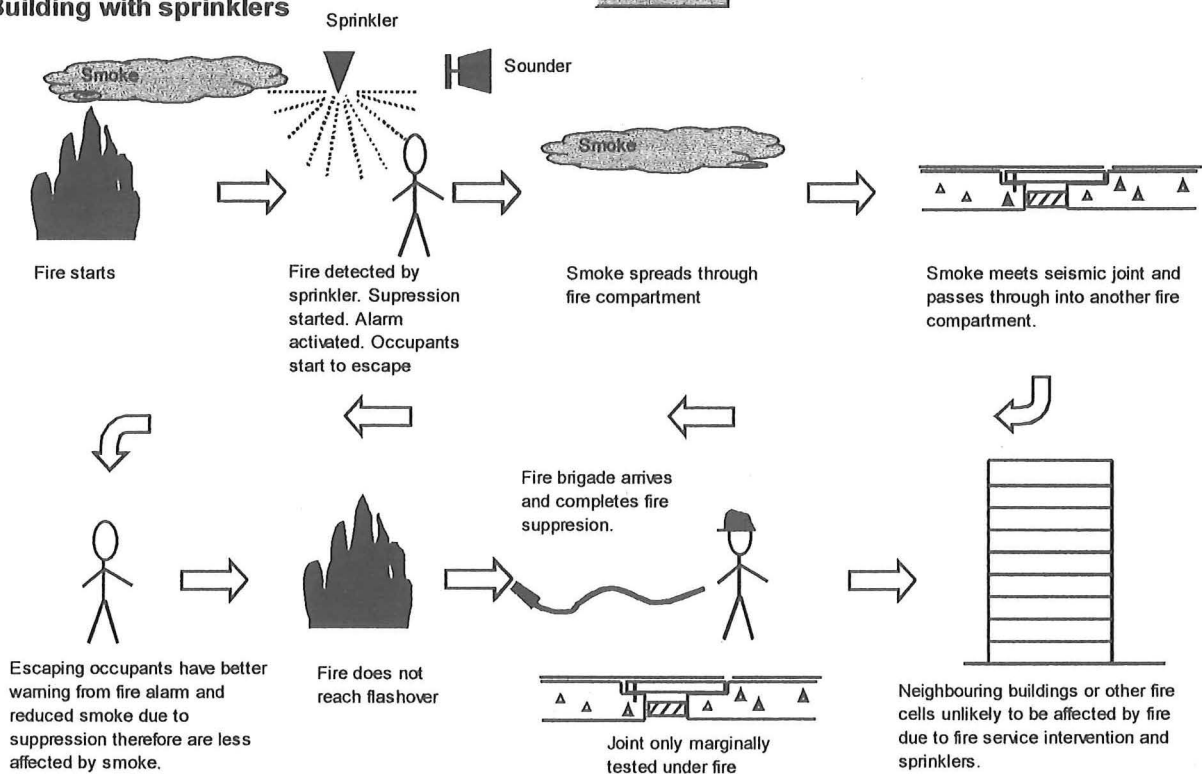
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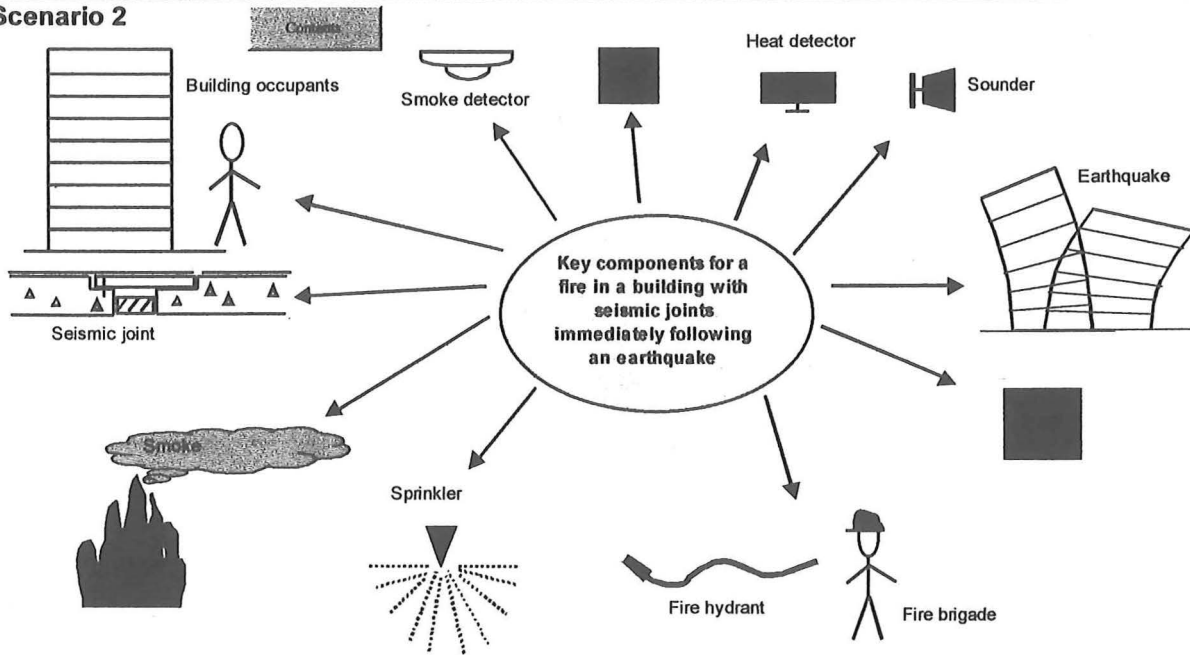
Scenario 1 - No Earthquake

Building with sprinklers

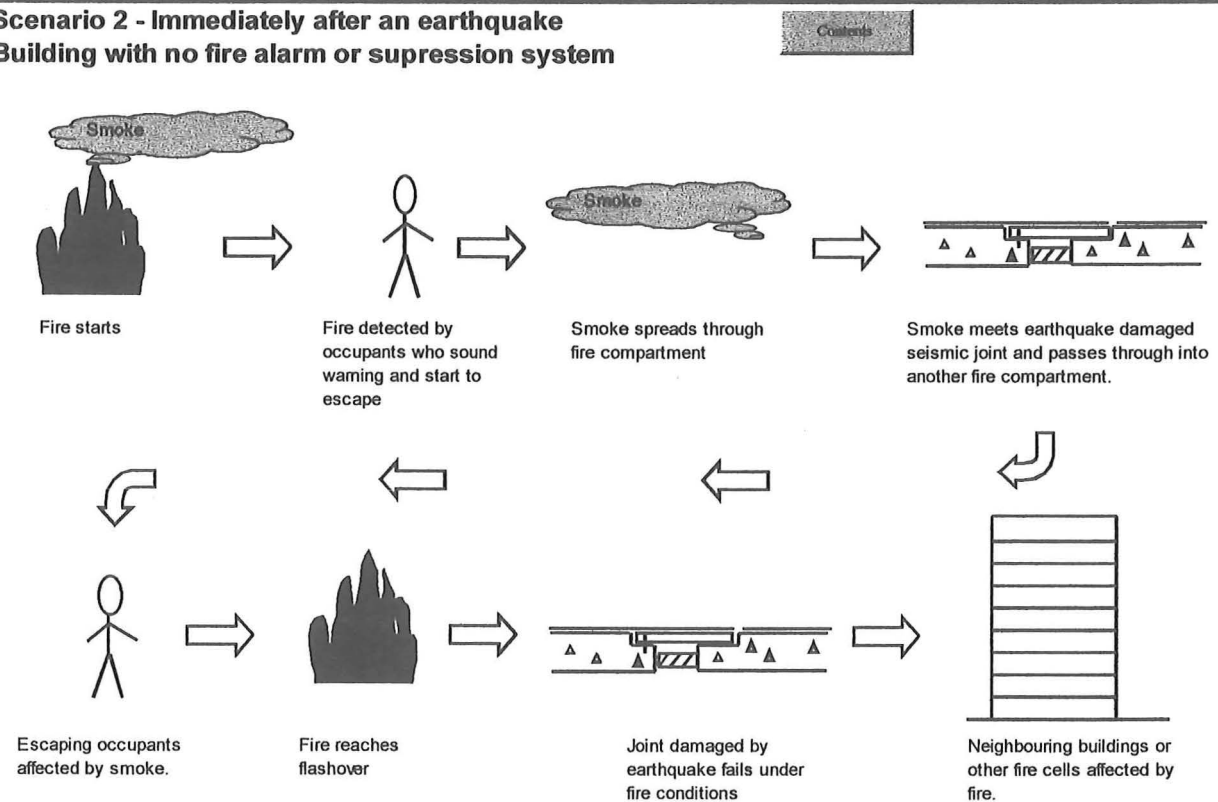
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Scenario 2

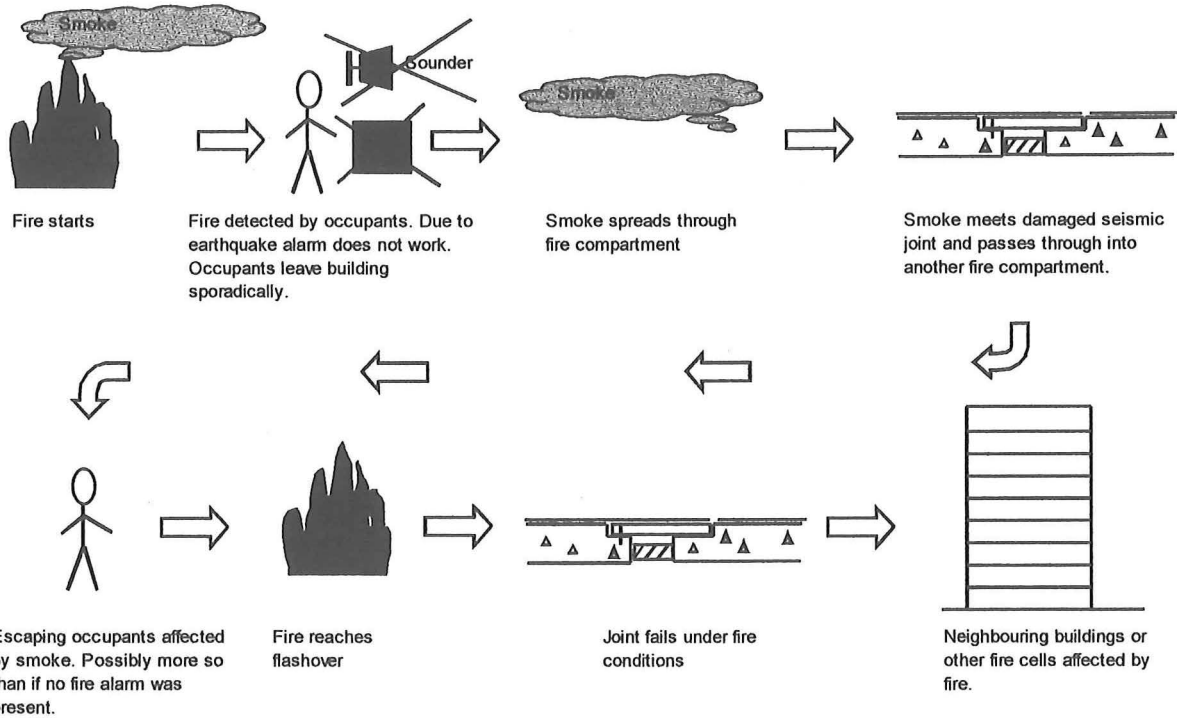


Scenario 2 - Immediately after an earthquake Building with no fire alarm or suppression system



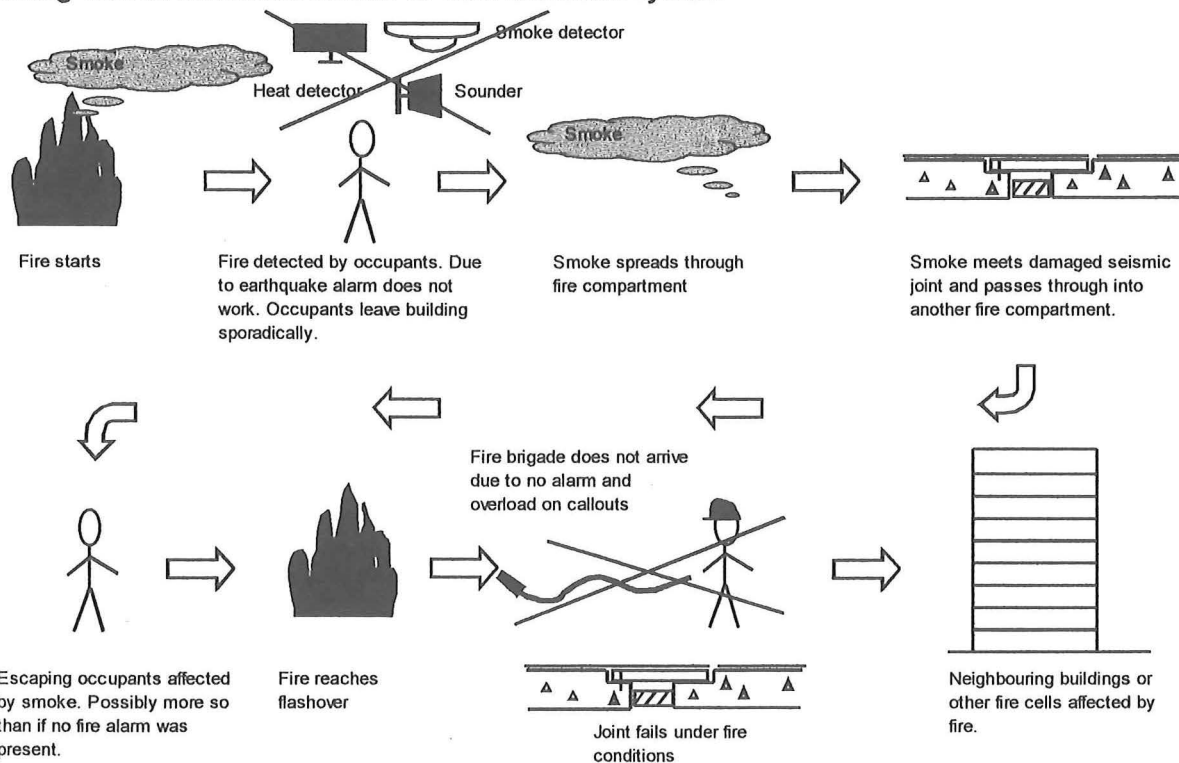
Scenario 2 - Immediately after an earthquake Building with a manual fire alarm system

Contents



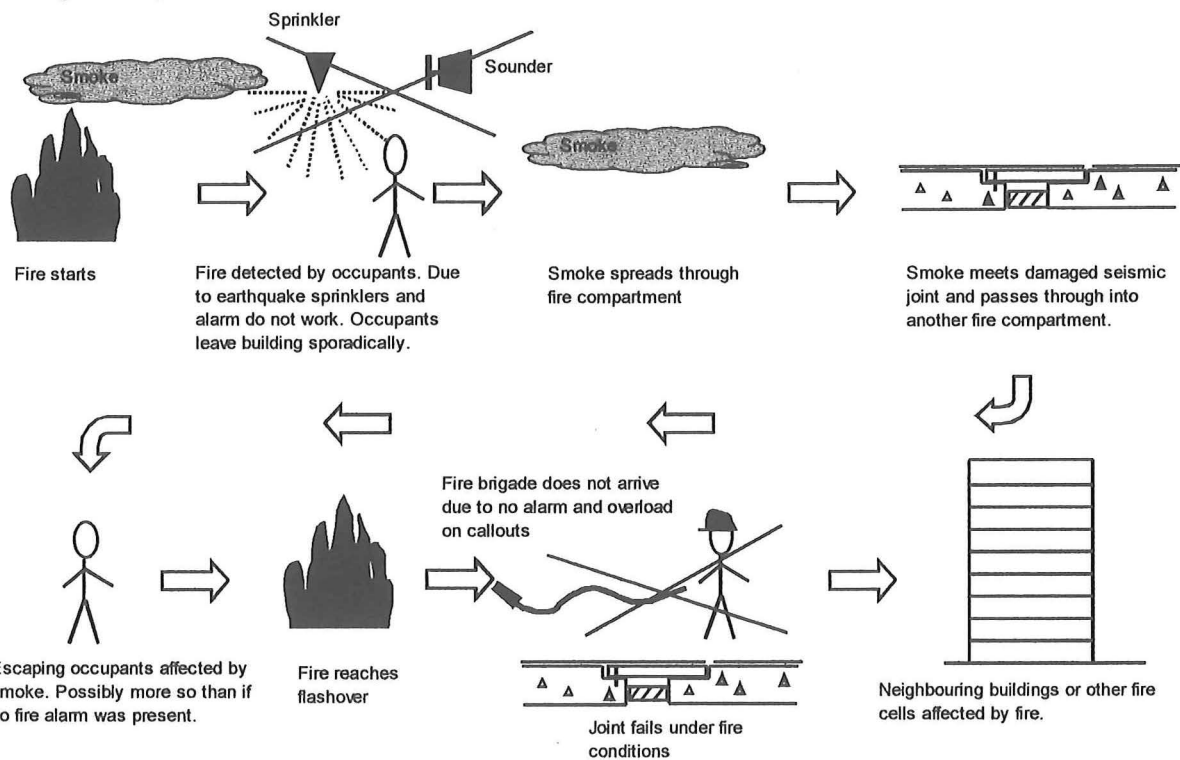
Scenario 2 - Immediately after an earthquake Building with an automatic smoke or heat detection system

Contents

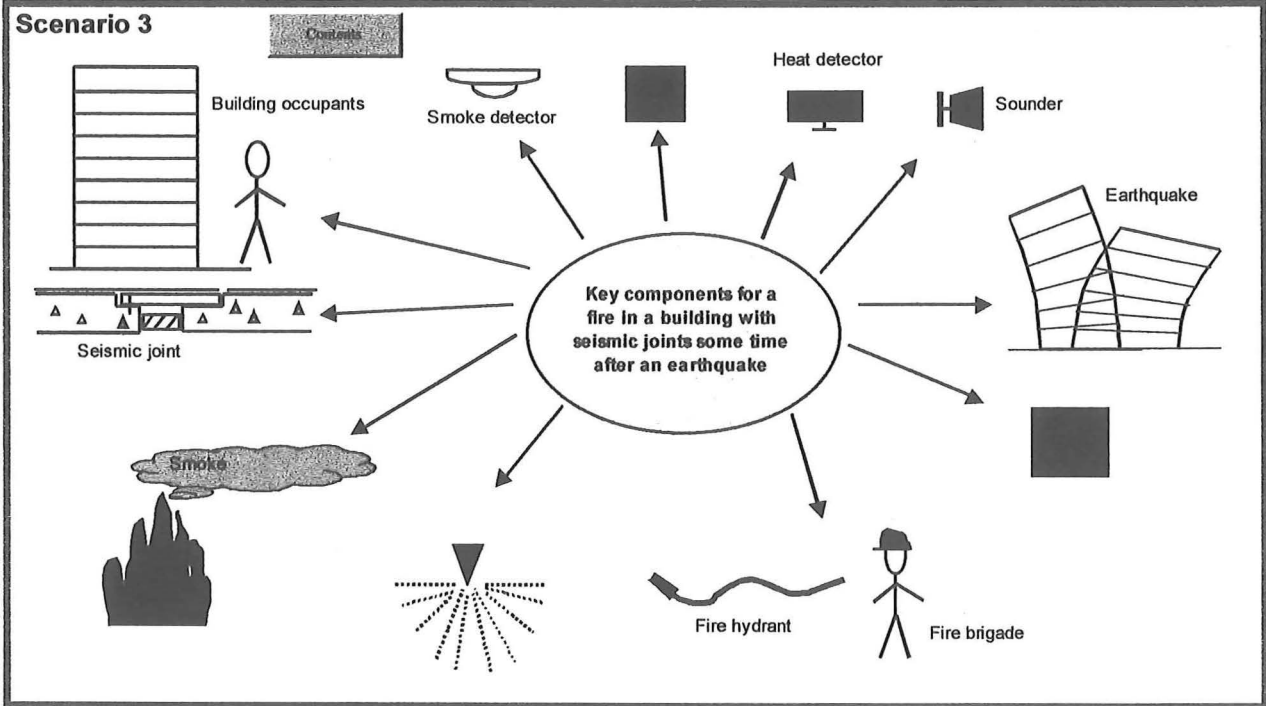


Scenario 2 - Immediately after an earthquake Building with sprinklers

Contents

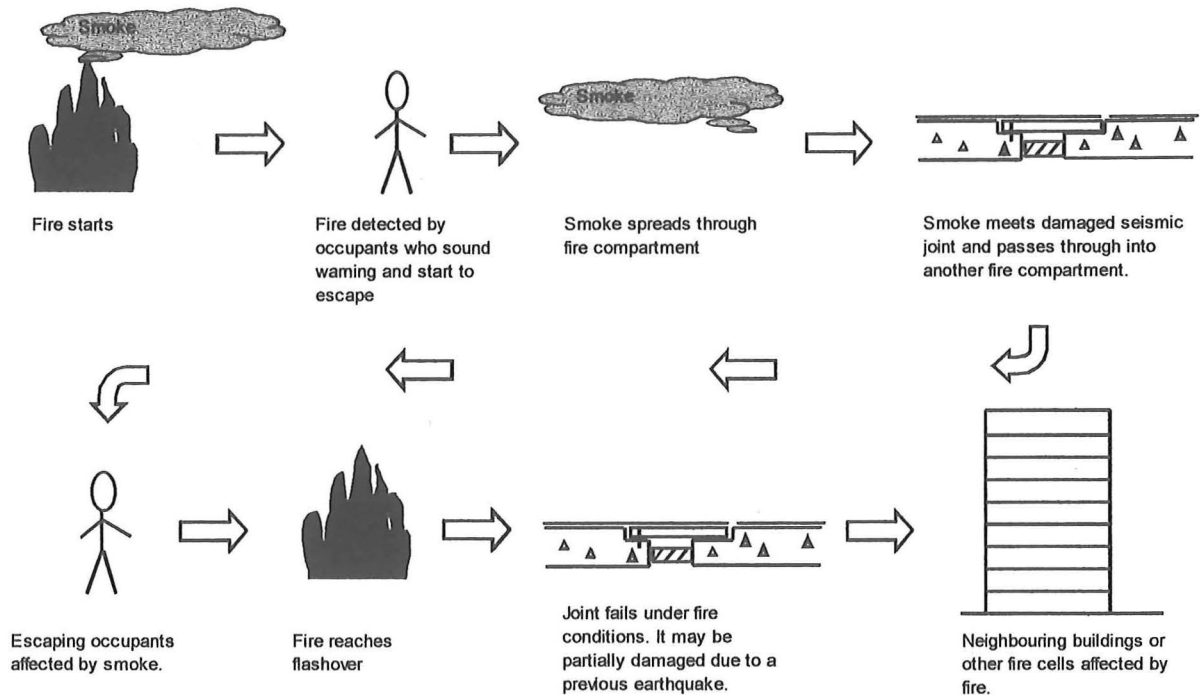


Scenario 3



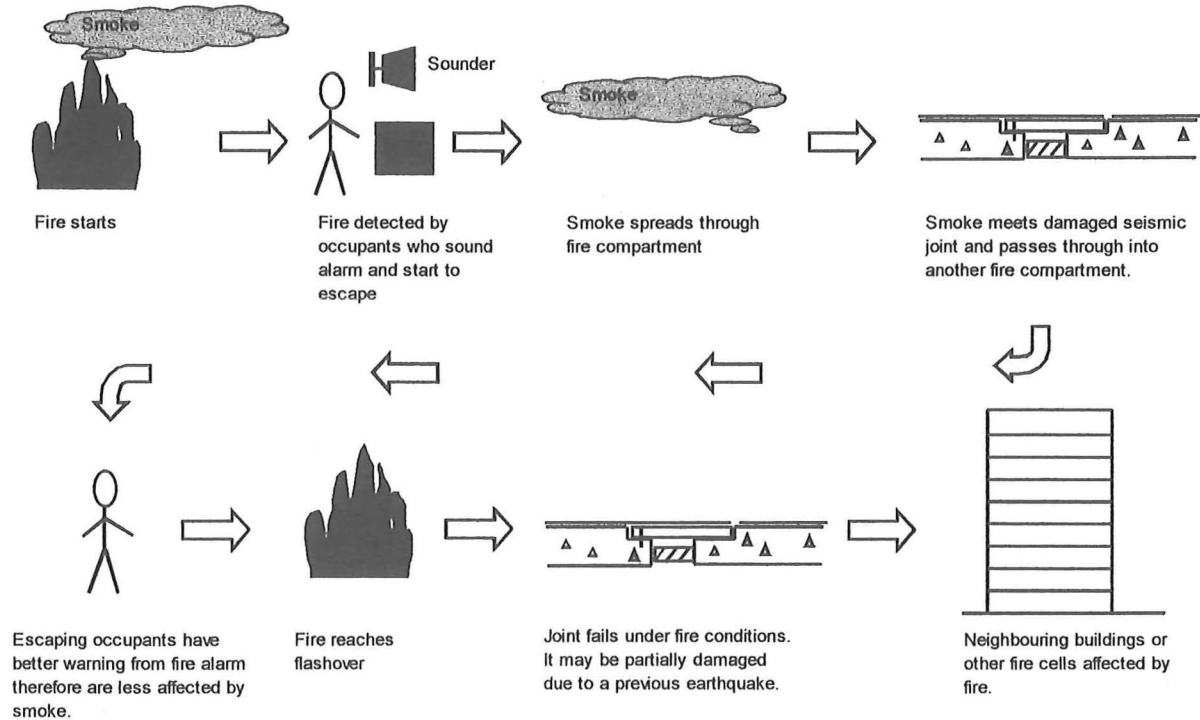
Scenario 3 - Some time after an earthquake Building with no fire alarm or suppression system

Contents



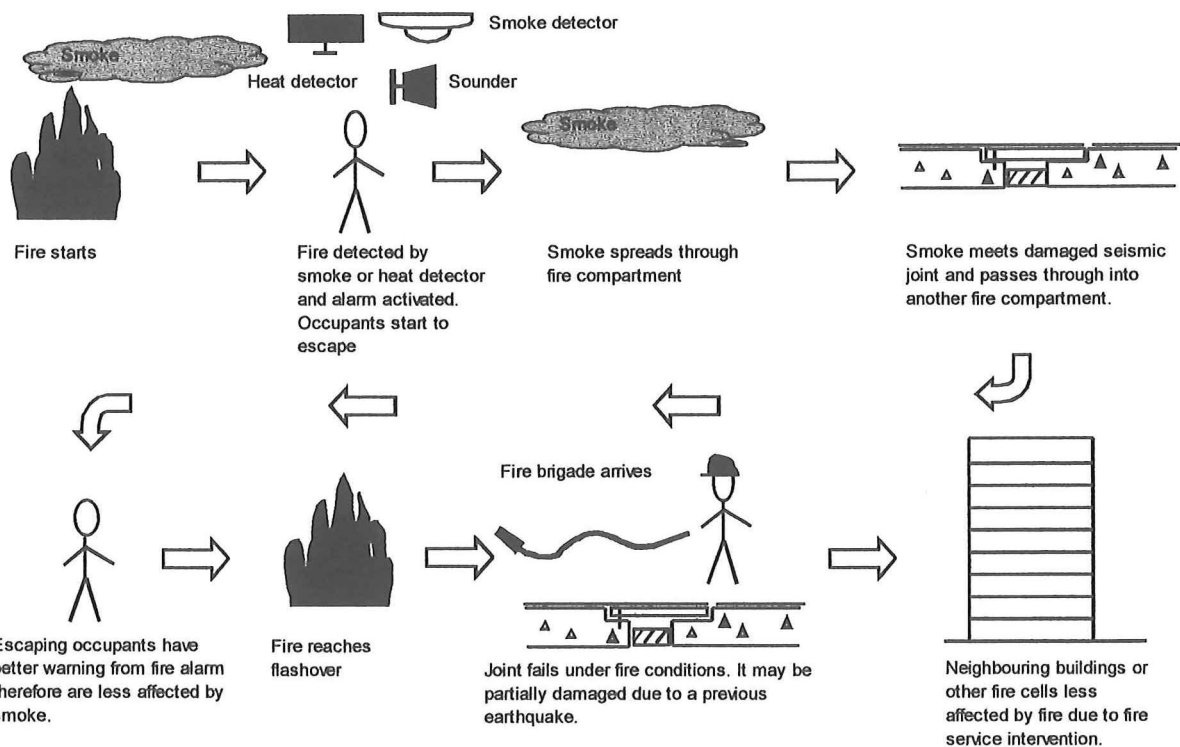
Scenario 3 - Some time after an earthquake Building with a manual fire alarm system

Contents



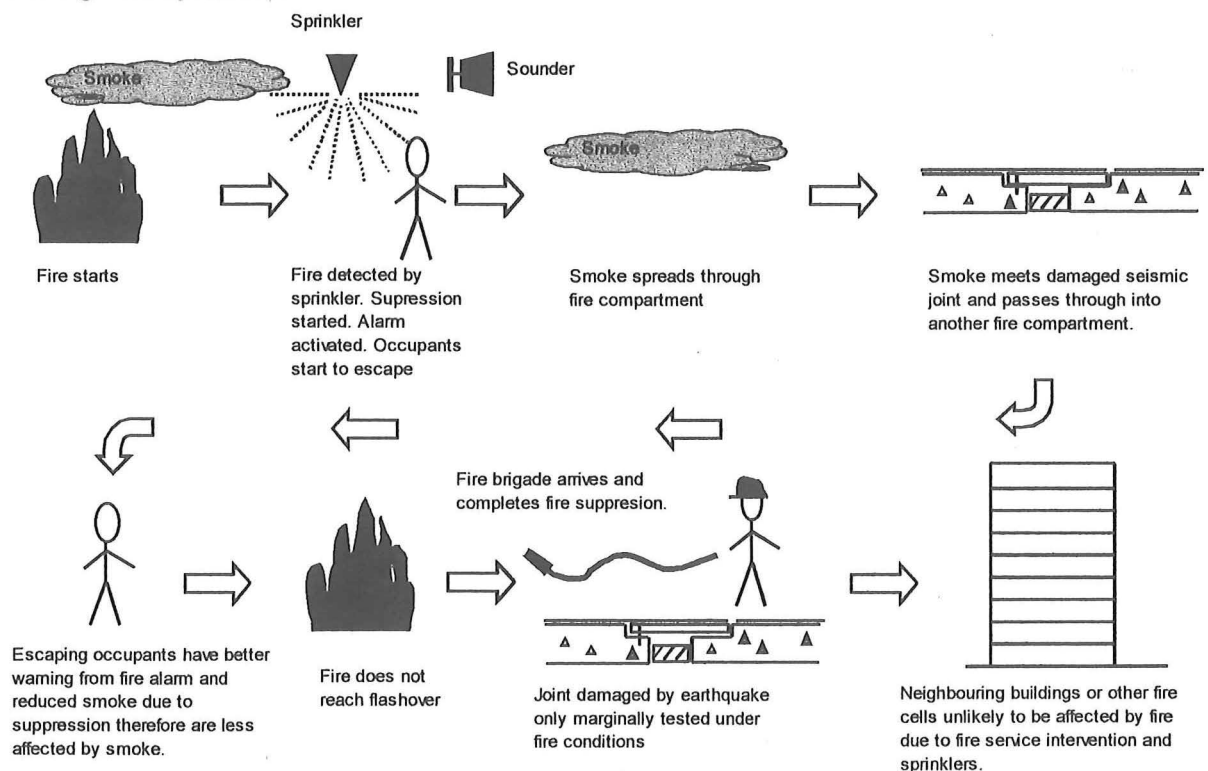
Scenario 3 - Some time after an earthquake Building with an automatic smoke or heat detection system

Contents



Scenario 3 - Some time after an earthquake Building with sprinklers

Contents



APPENDIX B

SEISMIC JOINT FAILURE ANALYSIS

Fire rated seismic joints **Floor and Wall joint Failure analysis**

before, immediately after, and long after an earthquake has occurred

Click on scenario below to go to the selected worksheet

Use case 1 - Floor joint prevents spread of smoke

Scenario 1 - Successful scenario

Scenario 2 - Failures with joint manufacturer

Scenario - Failures with joint specifier

Scenario 3 - Failure with builder and other contractors

Scenario 4 - Failures with installers

Scenario 5 - Failures with building occupants and owners

Scenario 6 - Failures due to the elapse of time

Scenario 7 - Failures due to environmental conditions

Scenario 8 - Failures due to building maintenance

Scenario 9 - Failures due to earthquake

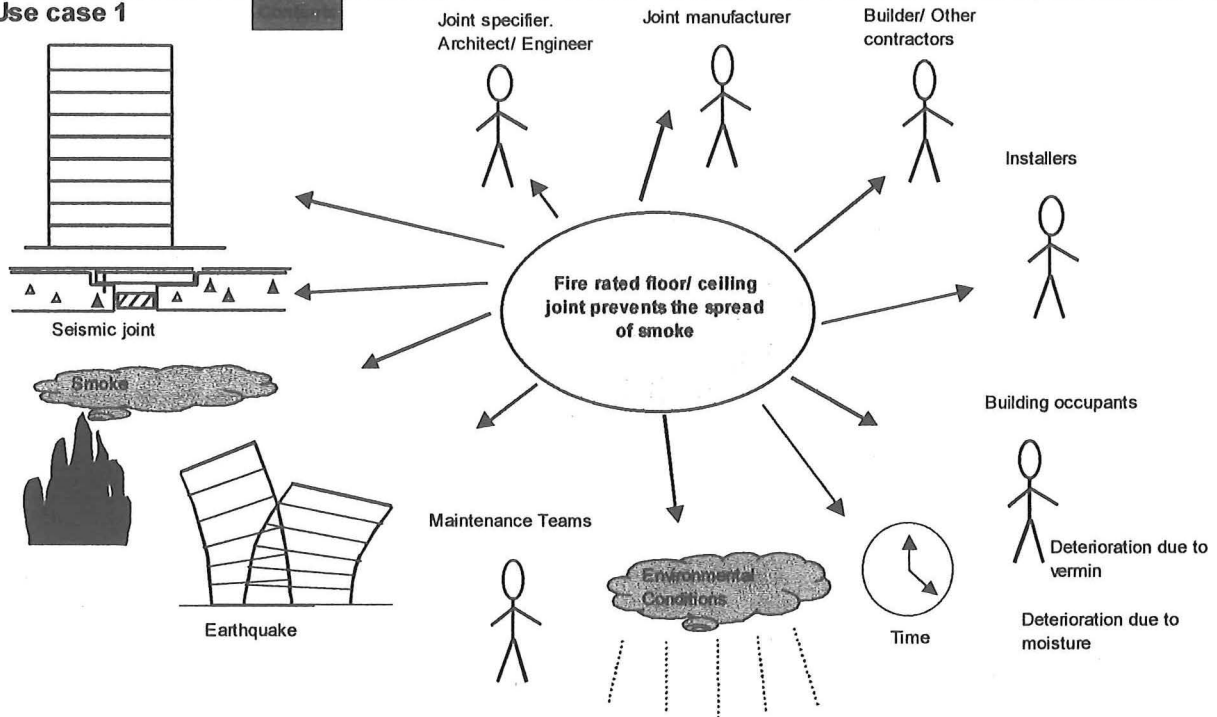
Scenario 10 - Failures during a fire

Use case 2 - Floor joint prevents the spread of fire

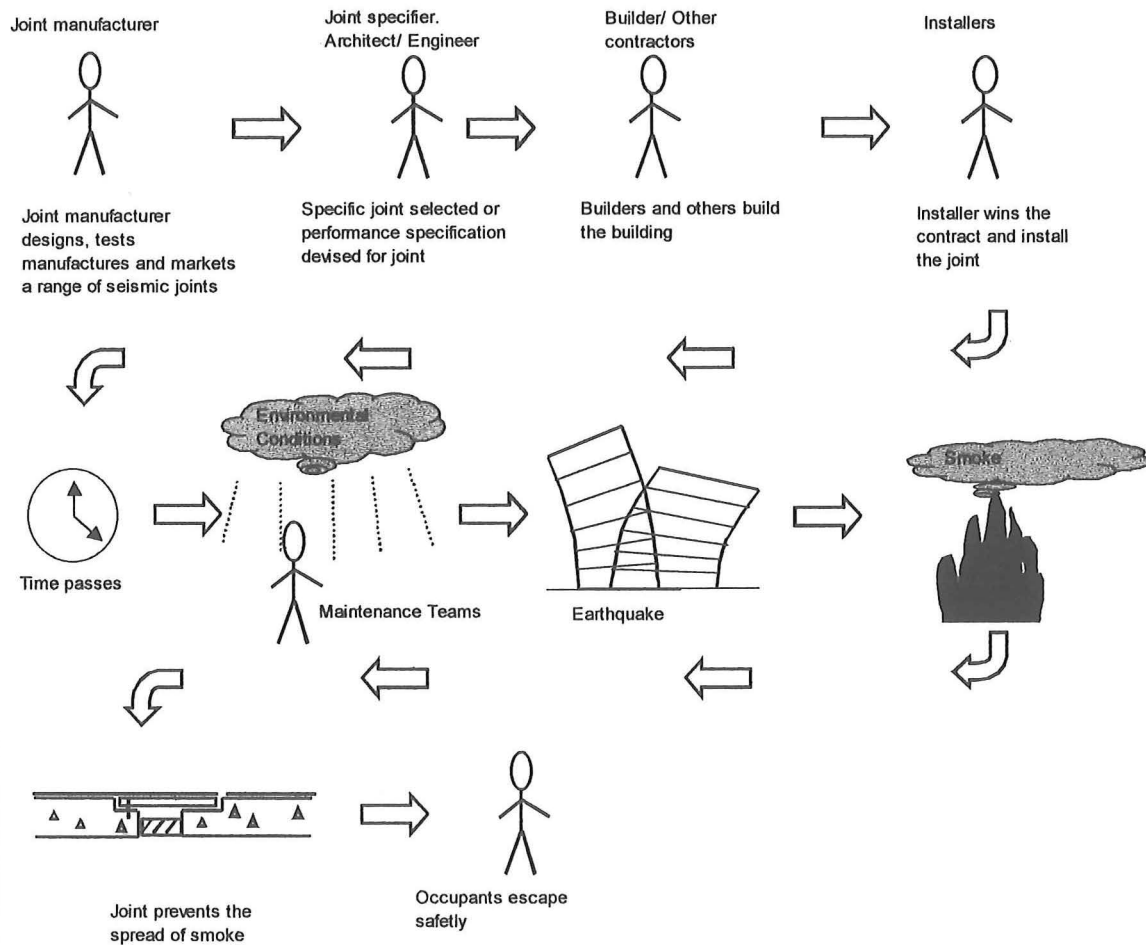
Scenario 1 - Successful scenario

Scenario 2 - Failures during a fire

Use case 1

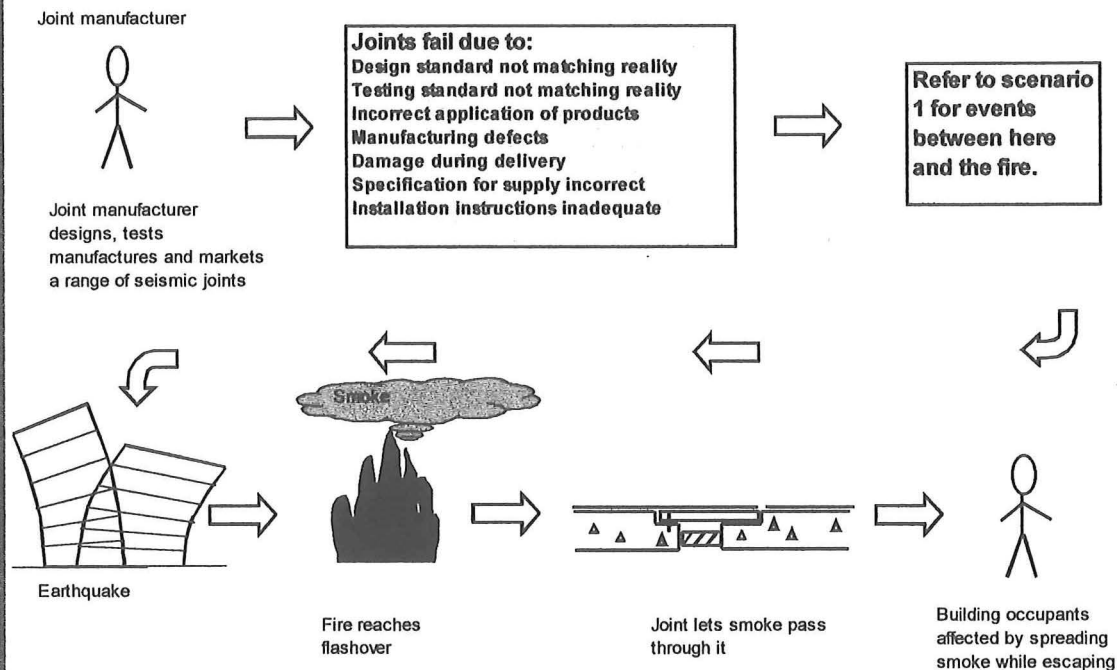


Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke **Successful scenario**



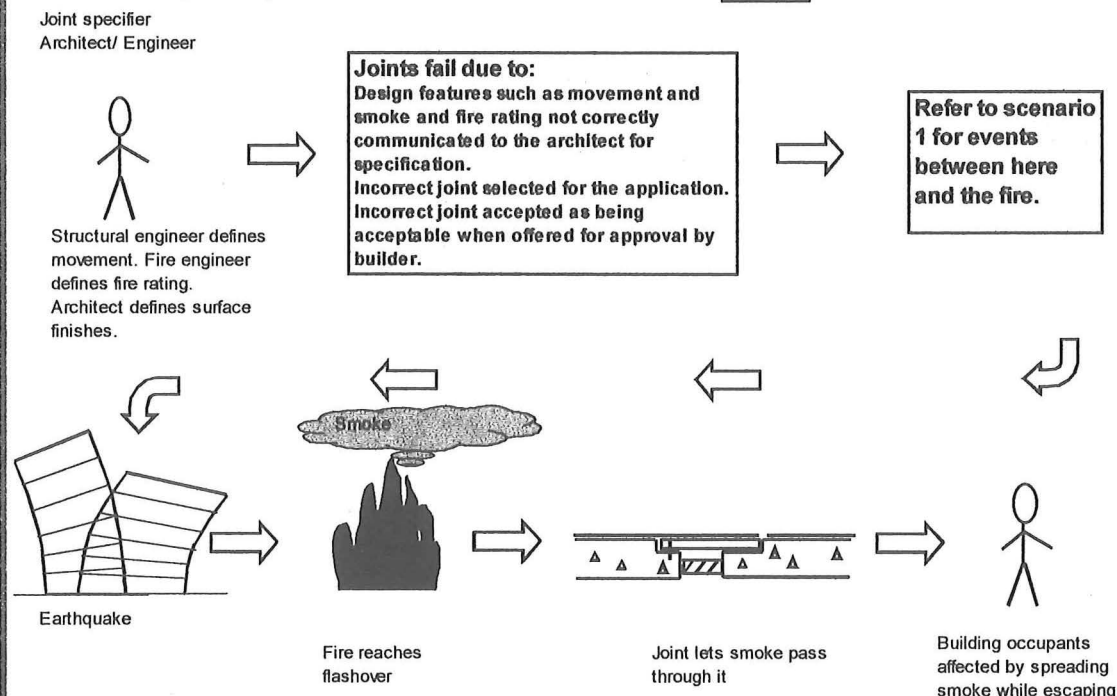
Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke

Failures with joint manufacturer



Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke

Failures with joint specifier



Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke

Failures with builder and other contractors

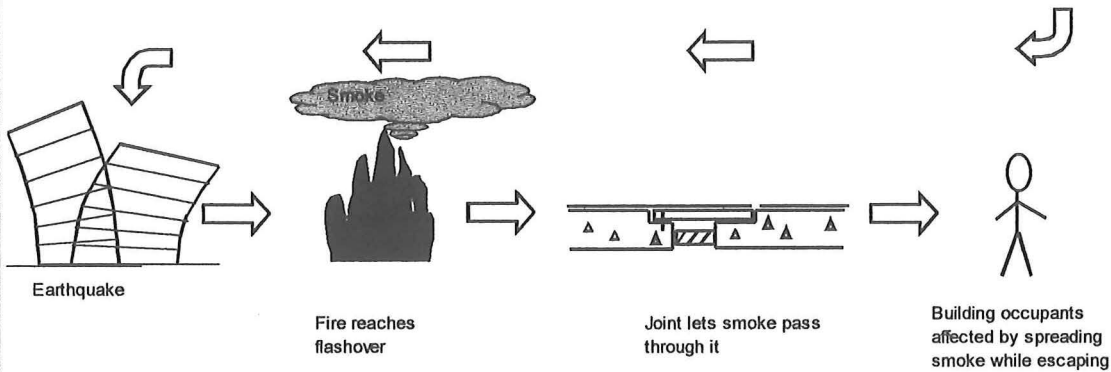
Builder/ Other contractors



Builders and others build the building

Joints fail due to:
Gap built larger than joint designed for.
Different joint chosen on price.
Damage during construction.
Other services pass through the joint.

Refer to scenario 1 for events between here and the fire.



Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke

Failures with Installers

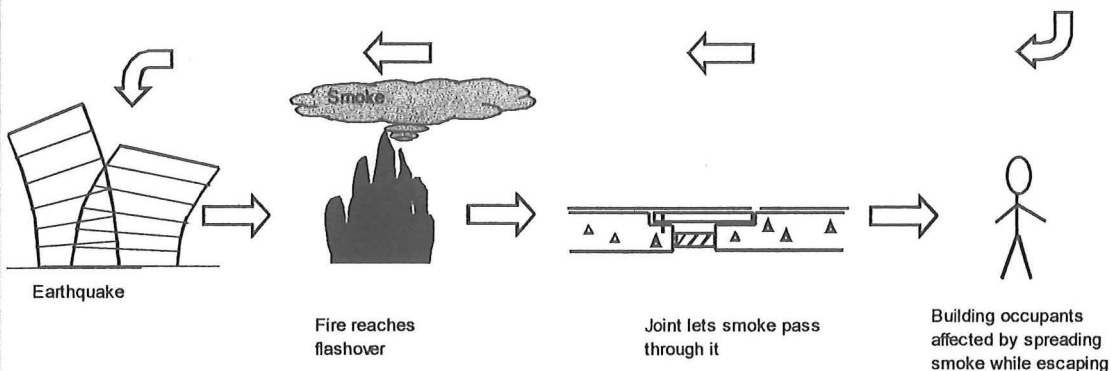
Installers



Installer wins the contract and install the joint

Joints fail due to:
Installation instructions incorrect.
Mistakes made during installation.
Installer not advised of required design movement.
Joint specified is not able to deal with all the variations in the seismic gap.

Refer to scenario 1 for events between here and the fire.



Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke

Failures with building occupants and owners

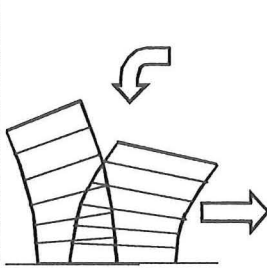
Building occupants/ owners



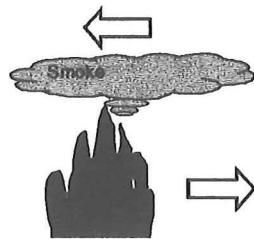
Joints fail due to:
Walls built over joints.
Joints damaged during refurbishment projects.
Joints removed due to inadequate knowledge of their purpose.



Refer to scenario 1 for events between here and the fire.



Earthquake



Fire reaches flashover



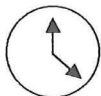
Joint lets smoke pass through it



Building occupants affected by spreading smoke while escaping

Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke

Failures due to the elapse of time



Time

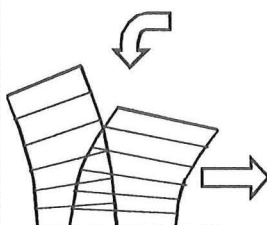
Time elapses during the building life.



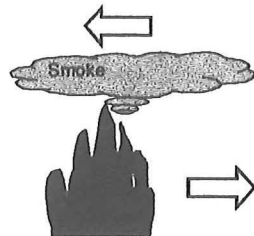
Joints fail due to:
Joint products deteriorate due to age.
Building is used beyond the expected life of the joint products.



Refer to scenario 1 for events between here and the fire.



Earthquake



Fire reaches flashover



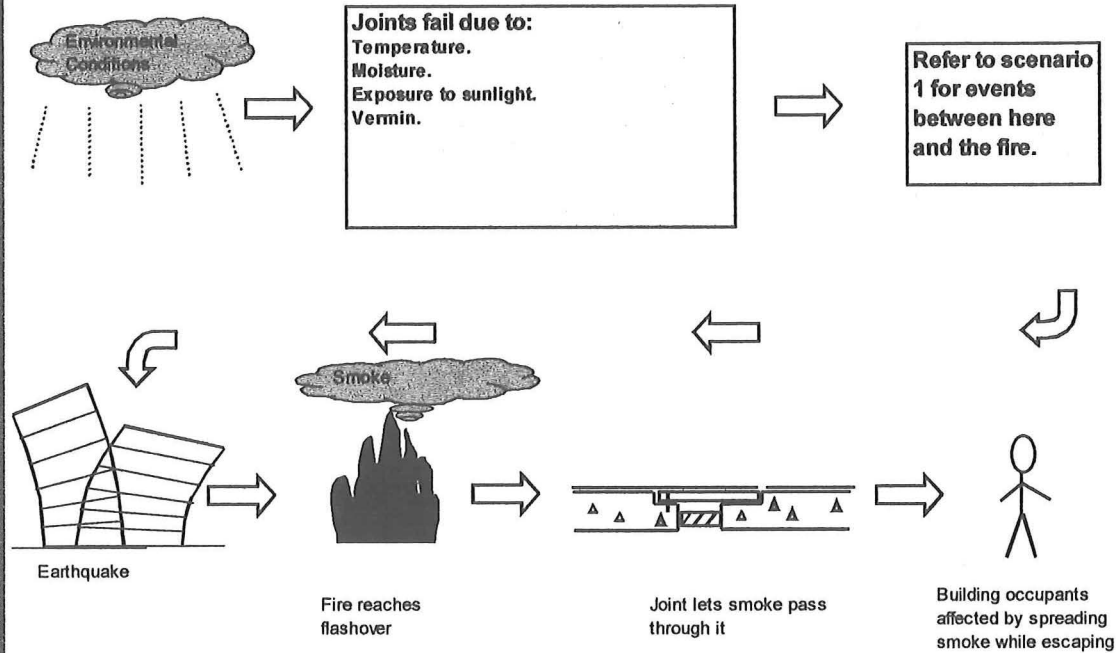
Joint lets smoke pass through it



Building occupants affected by spreading smoke while escaping

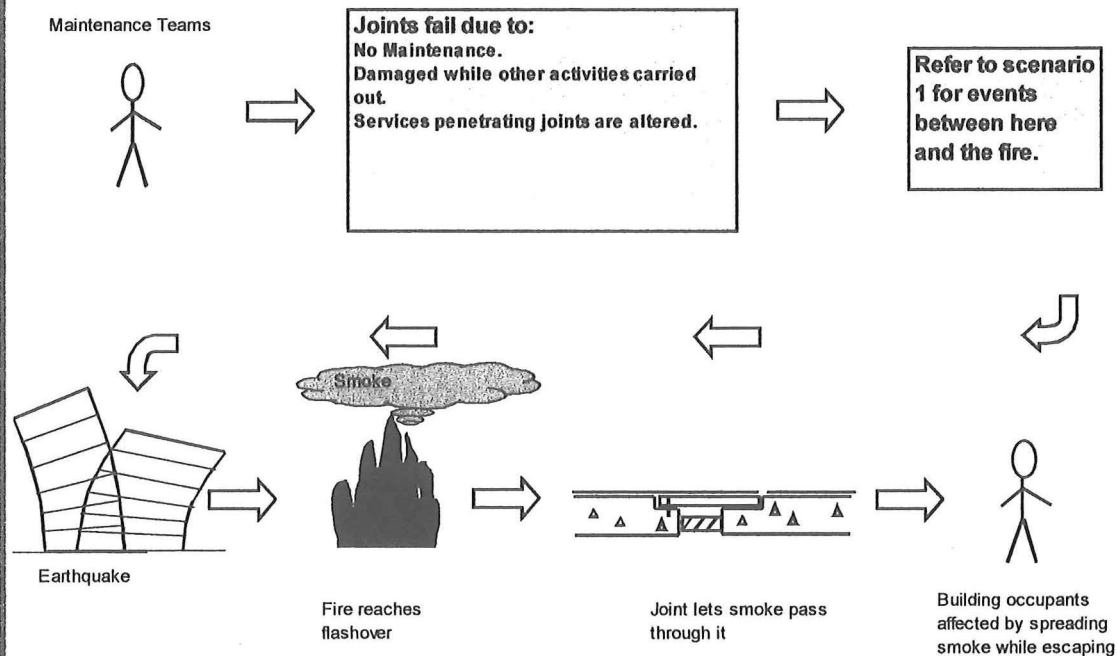
Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke

Failures due to environmental conditions



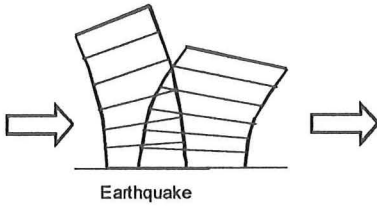
Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke

Failures due to building maintenance

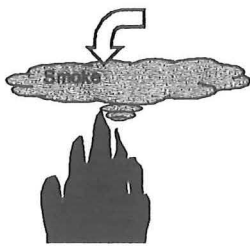


Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke
Failures due to earthquake

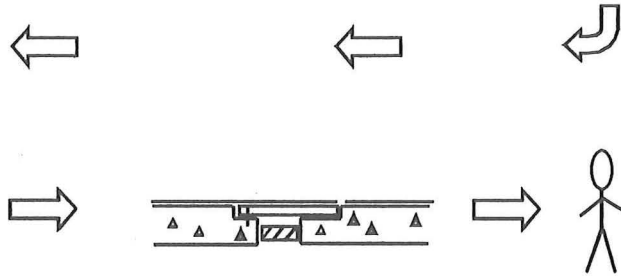
Refer to scenario 1 for events between here and the earthquake.



Joints fail due to:
 Earthquake larger than joint designed for.
 Movement is in directions not designed for.
 Joints not checked after a large earthquake.
 Damaged during building repair work after an earthquake.
 Repairs after an earthquake inadequate.



Fire reaches flashover

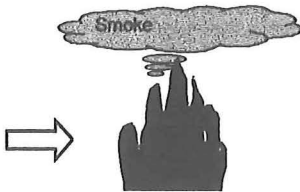


Joint lets smoke pass through it

Building occupants affected by spreading smoke while escaping

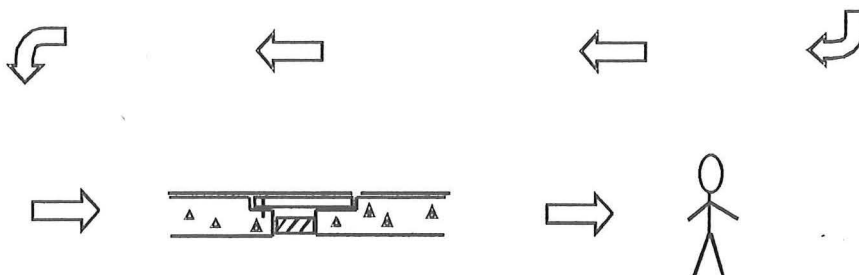
Use case 1 - Seismic floor/ ceiling joint prevents the spread of smoke
Failures during a fire

Refer to scenario 1 for events between here and the fire.



Fire reaches flashover

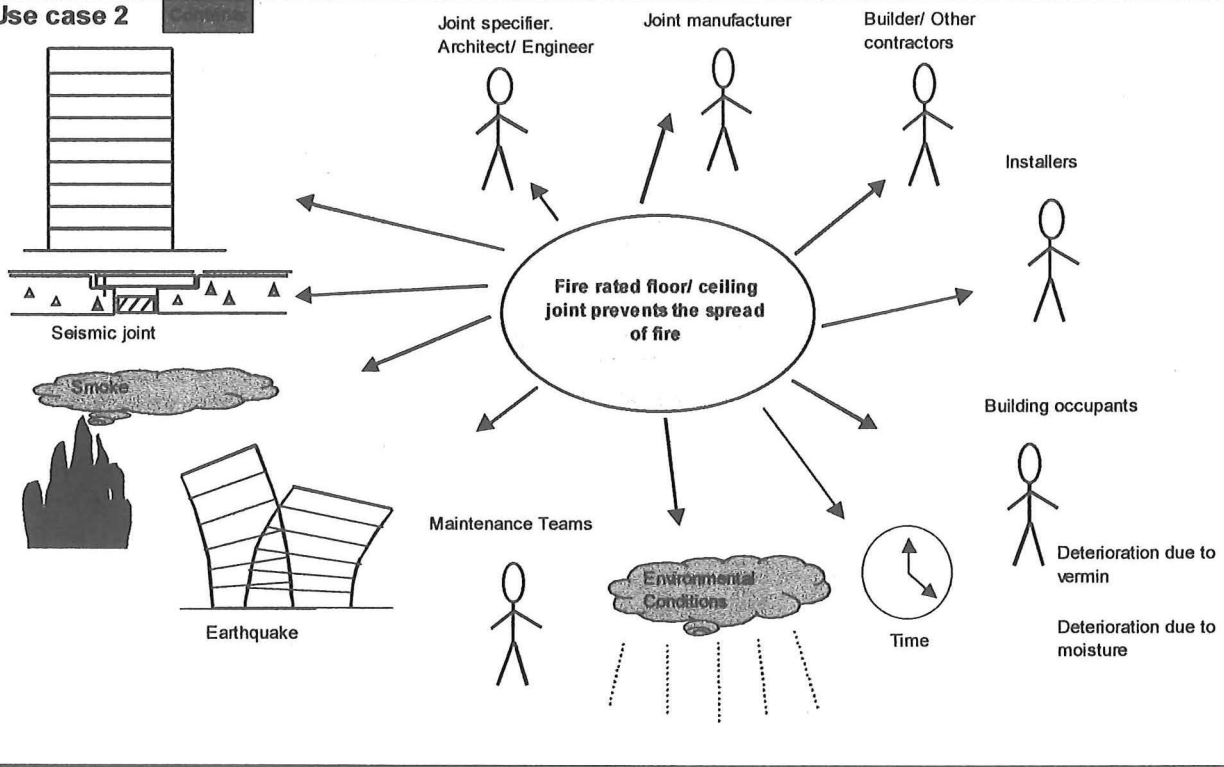
Joints fail due to:
 Inadequate smoke seals.
 Fire rating less than actual fire.
 Sprinklers are not operational so fire burns larger and longer.



Joint lets smoke pass through it

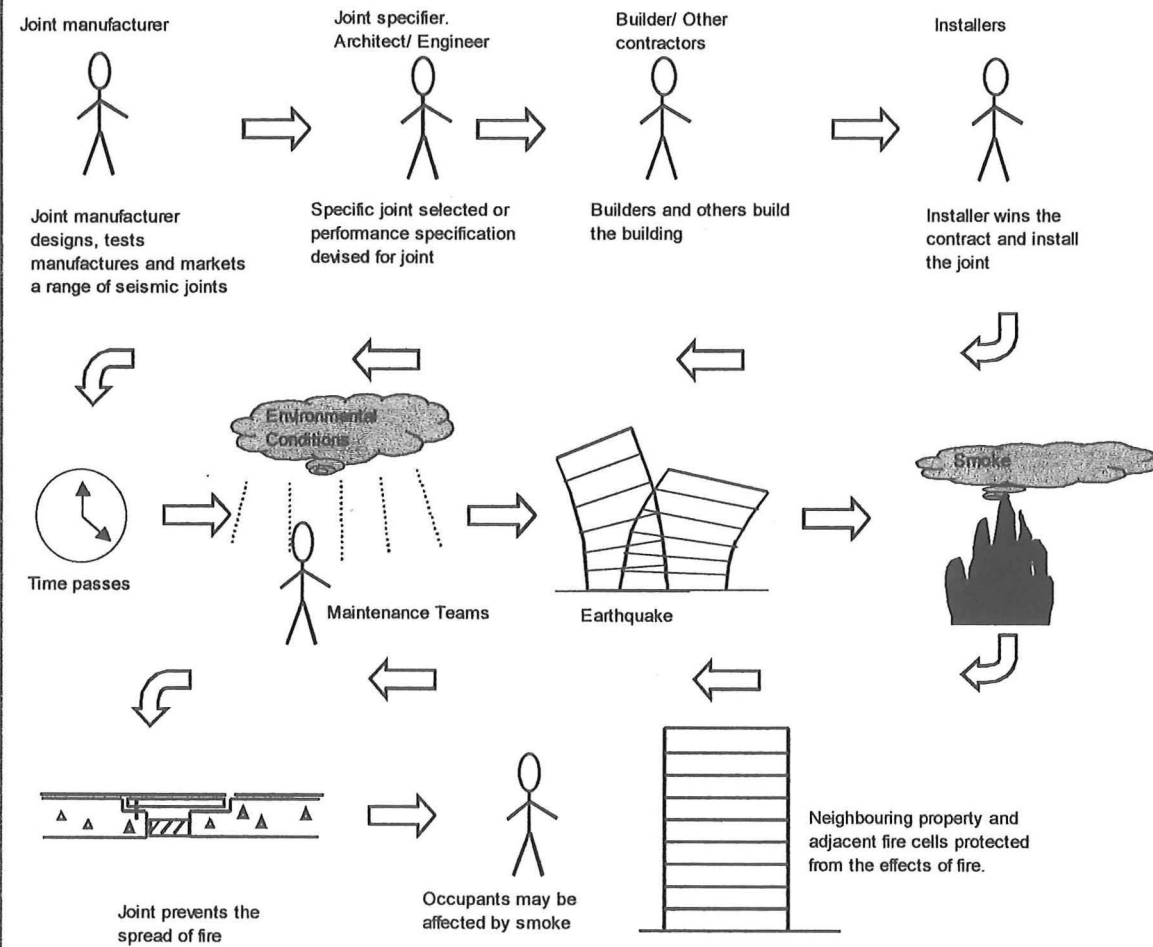
Building occupants affected by spreading smoke while escaping

Use case 2



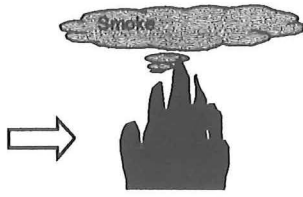
Use case 2 - Seismic floor/ ceiling joint prevents the spread of fire

Successful scenario



Use case 2 - Seismic floor/ ceiling joint prevents the spread of smoke
Failures during a fire

Refer to scenario
1 for events
between here
and the fire.



Fire reaches
flashover

Joints fail due to:
Fire rating less than actual fire.
Sprinklers are not operational
immediately after an earthquake so fire
burns larger and longer.
Water from sprinklers affect the
performance of the joint immediately or in
a future fire.



Joint lets smoke pass
through it



Building occupants
affected by spreading
smoke while escaping

APPENDIX C

WEBSITE HTML AND JAVASCRIPT CODE

Web site directory structure

Web pages are held in the root directory and images in the next level directory called indexes.

Web pages are:

- index.html
- contents.html
- indextop.html
- indexbottom.html
- mcalctop.html
- mcalcbottom.html
- visualtop.html
- visualbottom.html
- viewtop.html
- viewbottom.html
- spectop.html
- specbottom.html

The movement visualisation page calls on the javascript file DynEI.js

Images are contained in the images sub directory.

The html and javascript code for each page follows:

Index.html

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
  <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
  <META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">

  <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
  <TITLE>Seismic joint tools home</TITLE>
</HEAD>

<FRAMESET COLS = "20%,80% " BORDER="0" FRAMESPACING="0" FRAMEBORDER="NO">
  <FRAME SRC="contents.html" NAME="Frame1" RESIZE>
  <FRAMESET ROWS = "29%,71% " BORDER="0" FRAMESPACING="0"
FRAMEBORDER="NO">
    <FRAME SRC="indextop.html" NAME="Frame2" RESIZE>
    <FRAME SRC="indexbottom.html" NAME="Frame3" RESIZE>
  </FRAMESET>
</FRAMESET>

<NOFRAMES>
<BODY BACKGROUND="images/bckgrnd35.jpg" BGCOLOR="white" LINK="red" ALINK="yellow"
VLINK="red">

<P>

</BODY>

</NOFRAMES>

</HTML>
```

contents.html

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
  <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
  <META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">
  <SCRIPT LANGUAGE="JavaScript">
  <!-- Begin
function changePages(Frame2URL, Frame3URL){
  parent.Frame3.location.href=Frame3URL;
  parent.Frame2.location.href=Frame2URL;
}
  //end -->
</SCRIPT>

  <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
  <TITLE>Contents</TITLE>
</HEAD>

<BODY BACKGROUND="images/bckgrnd35.jpg" BGCOLOR="white" LINK="red" ALINK="yellow"
VLINK="red">

<H1><FONT COLOR="#CC0000" FACE="Arial, Helvetica">Seismic</FONT></H1>
<P><A HREF="javascript:changePages('indextop.html', 'indexbottom.html');"><B><FONT
FACE="Arial, Helvetica">Home</FONT></B></A></P>
```



```

<P><A HREF="javascript:changePages('mcalctop.html', 'mcalcbottom.html');"><B><FONT
FACE="Arial, Helvetica">Movement calculator</FONT></B></A></P>
<P><A HREF="javascript:changePages('visualtop.html', 'visualbottom.html');"><B><FONT
FACE="Arial, Helvetica">Movement visualisation</FONT></B></A></P>

<P><A HREF="javascript:changePages('viewtop.html', 'viewbottom.html');"><B><FONT FACE="Arial,
Helvetica">Joint viewer</FONT></B></A></P>

<P><A HREF="javascript:changePages('spectop.html', 'specbottom.html');"><B><FONT
FACE="Arial, Helvetica">Specification writer</FONT></B></A>

</BODY>

</HTML>

```

indextop.html

```

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
  <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
  <META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">

  <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
  <TITLE>indextop</TITLE>
</HEAD>

<BODY BGCOLOR="white">

<H1><FONT COLOR="#CC0000" FACE="Arial, Helvetica">Joint design tools</FONT><FONT
COLOR="#FF6666" FACE="Arial, Helvetica"></FONT></H1>
<P><A HREF="indexbottom.html#About" target="Frame3"><B><FONT SIZE="2" FACE="Arial,
Helvetica">About</FONT></B></A><B><FONT
SIZE="2" FACE="Arial, Helvetica"> || </FONT></B><A HREF="indexbottom.html#Technical"
target="Frame3"><B><FONT SIZE="2"
FACE="Arial, Helvetica">Technical</FONT></B></A><B><FONT SIZE="2" FACE="Arial, Helvetica">
|| </FONT></B><A HREF="indexbottom.html#Help"
target="Frame3"><B><FONT SIZE="2" FACE="Arial, Helvetica">Help</FONT></B></A>

</BODY>

</HTML>

```

indexbottom.html

```

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
  <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
  <META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">

  <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
  <TITLE>index bottom</TITLE>
</HEAD>

<BODY BGCOLOR="white">

<H3 ALIGN="CENTER"><B><FONT COLOR="green" FACE="Arial, Helvetica">This site requires at
least internet explorer

```

```

4 or Netscape 4</FONT></B></H3>
<P ALIGN="CENTER"><IMG SRC="images/sj013f.jpg" WIDTH="302" HEIGHT="200"
ALIGN="BOTTOM" BORDER="0"></P>
<P>
<H3><A NAME="About"></A><B><FONT COLOR="green" FACE="Arial,
Helvetica">About</FONT></B></H3>
<P><FONT FACE="Arial, Helvetica">The site has been built Michael James as part of a Canterbury
University Masters
in Fire Engineering research project.</FONT></P>

<P><FONT FACE="Arial, Helvetica">Researched showed that whilst progress was being made in the
area of specifications
for testing fire rated seismic joints there was a lack of knowledge in the building community as to the
magnitude
of movement to be expected and how joints may behave under such movement.</FONT></P>

<P><FONT FACE="Arial, Helvetica">The site presents a set of basic tools for determining how much
movement will
occcur, what the movement will look like, what generic type of joints can be used and a simple joint
specification.</FONT></P>

<P><FONT FACE="Arial, Helvetica">The site will be useful for manufacturers, engineers, architects,
quantity surveyors,
building owners, builders and installers.</FONT></P>
<H3><A NAME="Technical"></A><FONT COLOR="green" FACE="Arial,
Helvetica">Technical</FONT></H3>
<P><FONT FACE="Arial, Helvetica">Movement calculations are based on New Zealand Standard
NZS 4232.</FONT></P>
<P><FONT FACE="Arial, Helvetica">The site is programmed using javascript. Some of the features
are only available
to version 4 and higher browsers</FONT></P>
<H3><A NAME="Help"></A><FONT COLOR="green" FACE="Arial, Helvetica">Help</FONT></H3>
<P><FONT FACE="Arial, Helvetica">Click on a link to the left. Play around with the input options to
see the results
produced in this panel.</FONT></P>

<P><FONT FACE="Arial, Helvetica">To print out either use the print button or right click in the
frame</FONT>

</BODY>

</HTML>

```

mcalctop.html

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
  <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
  <META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">
  <SCRIPT LANGUAGE="JavaScript">

    //<!--
    function calculate() {
    // Get the data
    var height=document.movecalc.calc_building_height.value;
    var floors=document.movecalc.calc_num_floors.value;

    // Validate the data

    // subroutine to round numbers to 2 decimal places
    function round2(x) {
    return Math.round(x*100)/100;
    }

    // subroutine to round numbers to nearest whole number
    function round(x) {
    return Math.round(x);
    }

    // Do the calcs
    var floorht=round2(height/floors)

    var pf2d = parent.frames[2].document; // reduce the amount of typing to be done

    //print results
    pf2d.open();
    pf2d.write('<BODY BGCOLOR="#FFFFFF" TEXT="#000000" LINK="#0000FF" VLINK="#800080"
    ALINK="#FF0000">');
    pf2d.write('<FONT FACE="Arial, Helvetica"><H2><FONT COLOR="green" FACE="Arial,
    Helvetica">Seismic Movement data</font></H2>');
    pf2d.write('This building is <b>' + height + ' m high</b> and has <b>' + floors + '</b> floors');
    pf2d.write('<br>The floor to floor height is <b>' + floorht + ' m</b>');
    pf2d.write('<br>Remember for two buildings side by side the deflection is double.');
    pf2d.write('<br><P>Calculations are based on <b>NZS 4203: 1992</b>');
    pf2d.write('<br>Ultimate limit state deflection is to be used for category I and II buildings ');
    pf2d.write('i.e buildings dedicated to the preservation of life and buildings containing crowds. ');
    pf2d.write('<br>For buildings other than category I and II a lesser value could be used. ');
    pf2d.write('It is recommended that a value larger than the serviceability limit state due ');
    pf2d.write('to the difficulty in inspecting joints after they have been installed. ');
    pf2d.write('</P>');
    pf2d.write('<P>');
    pf2d.write('<P><TABLE BORDER="0" WIDTH="100%"><TR><TD WIDTH="100%">');
    pf2d.write('<TABLE ALIGN="Left" BORDER="1" CELSPACING="0" CELLPADDING="0"
    WIDTH="100%">');
    pf2d.write('<TR ALIGN="left" VALIGN="top">');
    pf2d.write('<TD ALIGN="left" VALIGN="top"><B>Floor</B></TD>');
    pf2d.write('<TD ALIGN="left" VALIGN="top"><B>Building<BR>Height<br>(m)</B></TD>');
    pf2d.write('<TD ALIGN="left"
    VALIGN="top"><B>Ultimate<BR>Interstorey<BR>deflection<br>(mm)</B></TD>');
    pf2d.write('<TD ALIGN="left" VALIGN="top"><B>Ultimate<br>Limit State
    <br>deflection<BR>(mm)</B></TD>');
```

```

pf2d.write('<TD ALIGN="left"
VALIGN="top"><B>Serviceability<BR>Interstorey<BR>deflection<br>(mm)</B></TD>');
pf2d.write('<TD ALIGN="left" VALIGN="top"><B>Serviceability<br>limit
state<br>deflection<BR>(mm)</B></TD></TR>');
for (var i = 1; i <= floors; i++) {
// Calculate deflections at iheight
var iheight = round2(i * height/floors)
if (iheight <= 15) {ultdef = round(iheight * 0.02 * 1000);
ultIntDef = round(floorht * 0.02 * 1000);
}
else if (iheight >= 30) {ultdef = round(((15 * 0.02) + (15 * 0.015) + ((iheight - 30) * 0.015)) * 1000);
ultIntDef = round(floorht * 0.015 * 1000);
}
else {ultdef = round((15 * 0.02 + (0.02 - (0.005 * (iheight - 15) / 15)) * (iheight - 15)) * 1000);
ultIntDef = round((0.02 - 0.005*(iheight - 15)/15) * floorht * 1000);
}
var servdef = round(ultdef / 6)
var servIntDef = round(ultIntDef / 6)
pf2d.write('<TR ALIGN="left" VALIGN="top">');
pf2d.write('<TD ALIGN="left" VALIGN="top">' + i + '</TD>');
pf2d.write('<TD ALIGN="left" VALIGN="top">' + iheight + '</TD>');
pf2d.write('<TD ALIGN="left" VALIGN="top">' + ultIntDef + '</TD>');
pf2d.write('<TD ALIGN="left" VALIGN="top">' + ultdef + '</TD>');
pf2d.write('<TD ALIGN="left" VALIGN="top">' + servIntDef + '</TD>');
pf2d.write('<TD ALIGN="left" VALIGN="top">' + servdef + '</TD></TR>');
}
pf2d.write('</TABLE>'); //close the table
pf2d.write('</P>');
pf2d.write('</TD></TR>');
pf2d.write('<TR><TD WIDTH="100%">');
pf2d.write('<FONT FACE="Arial, Helvetica">Note that these deflections are the maximum deflections
permitted by the code. Many buildings ');
pf2d.write('will have less deflection under a design earthquake. It is essential to consult the structural
engineer for the building.</FONT>');
pf2d.write('</TD></TR></TABLE></P>');
pf2d.write('</FONT>');
pf2d.write('</BODY>');

pf2d.close();
}

//end -->

</SCRIPT>

<META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
<TITLE>movement calculator top page</TITLE>
</HEAD>

<BODY BGCOLOR="white">

<FORM METHOD="GET" name="movecalc" onsubmit="calculate()">
<H1><FONT COLOR="#CC0000" FACE="Arial, Helvetica">Movement calculator</FONT></H1>
<P><B><FONT SIZE="2" FACE="Arial, Helvetica">Enter Building height (m): </FONT></B><FONT
SIZE="2" FACE="Arial, Helvetica">
<INPUT TYPE="TEXT" NAME="calc_building_height" SIZE="6"
MAXLENGTH="6"></FONT><B><FONT SIZE="2" FACE="Arial, Helvetica">Number
of floors: </FONT></B><FONT SIZE="2" FACE="Arial, Helvetica"><INPUT TYPE="TEXT"
NAME="calc_num_floors" SIZE="4"
MAXLENGTH="5"></FONT><B>&nbsp;&nbsp;&nbsp;<A HREF="javascript:calculate();"><FONT SIZE="2"
FACE="Arial, Helvetica">Go!</FONT></A></B>

```

</FORM>

</BODY>

</HTML>

mcalcbottom.html

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">

<HTML>

<HEAD>

<META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">

<META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">

<META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">

<TITLE>mcalc bottom frame page</TITLE>

</HEAD>

<BODY BGCOLOR="white">

<P>

</P>

<H3 ALIGN="CENTER">Enter building height and number of floors then
press Go!</H3>

<H3 ALIGN="CENTER">A table showing horizontal deflections for each level will appear here.</H3>

<H3 ALIGN="CENTER">Click here for the design basis</H3>

<H3 ALIGN="CENTER">

Design Basis</H3>

<P>The design is based on NZS 4203:1992 "Code of practice for General Structural Design and Design Loadings for Buildings".</P>

<P>The formula for ultimate limit state deflection at building height h_{n} is </P>

<P>

<TABLE BORDER="0" WIDTH="100%">

<TR>

<TD WIDTH="33%"> </TD>

<TD WIDTH="33%"> 0.02 *

h_{n}</TD>

<TD WIDTH="34%">for h_{n}

<U><</U> 15m</TD>

</TR>

<TR>

<TD WIDTH="33%"> </TD>

<TD WIDTH="33%"> 0.015 *

h_{n}</TD>

<TD WIDTH="34%">for h_{n}

<U>></U> 30m</TD>

</TR>

<TR>

<TD WIDTH="33%"> </TD>

<TD WIDTH="33%"> (0.02-0.005)*(

h_{n}-15)/15*h<SUB><FONT

FACE="Arial, Helvetica">n</SUB>

</TD>

<TD WIDTH="34%">for 15 m <

h_{n}<

30m</TD>

</TR>

</TABLE>

</P>

<P>The serviceability limit state deflection is 1/6 of the ultimate limit state deflection.</P>

<P>

</BODY>

</HTML>

visualtop.html

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
  <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
<META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">

  <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
  <TITLE>Movement visualisation top</TITLE>
</HEAD>

<BODY BGCOLOR="white">

<FORM ACTION="#" METHOD="POST" ENCTYPE="application/x-www-form-urlencoded"
NAME="movement">
<H1><FONT COLOR="#CC0000" FACE="Arial, Helvetica">Movement visualisation</FONT></H1>
<P><B><FONT SIZE="2" FACE="Arial, Helvetica">Select joint type:</FONT></B>
<FONT SIZE="2" FACE="Arial, Helvetica">

<SELECT NAME="jointType" onChange="parent.Frame3.location.href='floorvis.html';">
<OPTION SELECTED> </OPTION>
<OPTION>Floor joint</OPTION>
<OPTION>Wall joint</OPTION>
<OPTION>Wall/ Floor joint</OPTION>
</SELECT>
</FONT><BR>
<B><FONT SIZE="2" FACE="Arial, Helvetica">Static Gap=</FONT></B><FONT SIZE="2"
FACE="Arial, Helvetica"><INPUT TYPE="TEXT"
NAME="statg" SIZE="5" MAXLENGTH="3" VALUE="0"></FONT><B><FONT SIZE="2" FACE="Arial,
Helvetica"> Movement (+/- mm):
Axial </FONT></B><FONT SIZE="2" FACE="Arial, Helvetica">=<INPUT TYPE="TEXT"
NAME="movx" SIZE="5" MAXLENGTH="3"
VALUE="0"> </FONT><B><FONT SIZE="2" FACE="Arial, Helvetica">Shear </FONT></B><FONT
SIZE="2" FACE="Arial, Helvetica">=<INPUT
TYPE="TEXT" NAME="movy" SIZE="5" MAXLENGTH="3" VALUE="0"></FONT><B><FONT
SIZE="2" FACE="Arial, Helvetica">Vertical
=</FONT></B><FONT SIZE="2" FACE="Arial, Helvetica"><INPUT TYPE="TEXT" NAME="movz"
SIZE="5" MAXLENGTH="3" VALUE="0"></FONT>
</FORM>

</BODY>

</HTML>
```

visualbottom.html

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
  <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
<META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">

  <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
  <TITLE>visual bottom</TITLE>
</HEAD>

<BODY BGCOLOR="white">
```

<P></P>

<P>

</P>

<H3 ALIGN="CENTER">Select a seismic joint type
then adjust the static
gap and movement to see it in motion here!

</BODY>

</HTML>

viewtop.html

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
    <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
    <META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">
    <SCRIPT LANGUAGE="JavaScript">
    //<!-- Begin
    function selectPage(){

    var i=document.jviewer.imgNum.value;

    // get the data;
    var wSopt=document.jviewer.whichShow.selectedIndex;

    // Set some variables for calling the images
    if (wSopt == 0) {parent.Frame3.location.href='viewbottom.html';
    }
    if (wSopt == 1) {imgName = 'sjloca';
        imgMax = 8;
    }
    if (wSopt == 2) {imgName = 'fjcomp';
        imgMax = 8;
    }
    if (wSopt == 3) {imgName = 'wjcomp';
        imgMax = 8;
    }
    if (wSopt == 4) {imgName = 'sjprob';
        imgMax = 12;
    }
    if (i > imgMax) {i = 1;
        document.jviewer.imgNum.value = 1;
    }
    if (i < 1) {i = imgMax;
        document.jviewer.imgNum.value = imgMax;
    }

    // display the image
    var pf2d = parent.frames[2].document; // reduce the amount of typing to be done
    pf2d.open();
    pf2d.write('<BODY BGCOLOR="#FFFFFF" TEXT="#000000" LINK="#0000FF" VLINK="#800080"
    ALINK="#FF0000">');
    pf2d.write('<FONT FACE="Arial, Helvetica"><H2 ALIGN="CENTER"><FONT COLOR="green"
    FACE="Arial, Helvetica">Fire rated seismic joint</font></H2>');
    pf2d.write('<p ALIGN="CENTER"></p>');
    pf2d.write('</BODY>');

    pf2d.close();
    }
    //end -->
</SCRIPT>

    <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
    <TITLE>Joint viewer</TITLE>
</HEAD>

<BODY BGCOLOR="white">
```

```

<FORM METHOD="GET" NAME="jviewer">
<H1><FONT COLOR="#CC0000" FACE="Arial, Helvetica">Joint viewer</FONT></H1>
<P>
<TABLE BORDER="0" WIDTH="100%">
  <TR>
    <TD WIDTH="25%"><B><FONT COLOR="black" FACE="Arial, Helvetica">Select an
option</FONT></B></TD>
    <TD WIDTH="17%">
      <SELECT NAME="whichShow" onChange="selectPage()">
        <OPTION SELECTED>Select </OPTION>
        <OPTION>Joint locations</OPTION>
        <OPTION>Floor joints</OPTION>
        <OPTION>Wall joints</OPTION>
        <OPTION>Joint problems</OPTION>
      </SELECT>
    </TD>
    <TD WIDTH="6%"></TD>
    <TD WIDTH="5%"><A HREF="javascript:document.jviewer.imgNum.value =
eval(document.jviewer.imgNum.value) - 1; selectPage();"><IMG
SRC="images/b42.gif" WIDTH="40" HEIGHT="43" ALIGN="BOTTOM"
BORDER="0"></A></TD>
    <TD WIDTH="6%"><INPUT TYPE="TEXT" NAME="imgNum" SIZE="2"
MAXLENGTH="2" VALUE="1" onChange="selectPage();"></TD>
    <TD WIDTH="41%"><A HREF="javascript:document.jviewer.imgNum.value =
eval(document.jviewer.imgNum.value) + 1; selectPage();"><IMG
SRC="images/b38.gif" WIDTH="42" HEIGHT="43" ALIGN="BOTTOM"
BORDER="0"></A></TD>
  </TR>
</TABLE>

</FORM>

</BODY>

</HTML>

```

viewbottom.html

```

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
  <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
  <META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">

  <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
  <TITLE>check bottom</TITLE>
</HEAD>

<BODY BGCOLOR="white">

<P>
<P><BR>
<BR>
<BR>
</P>
<H3 ALIGN="CENTER"><FONT COLOR="green" FACE="Arial, Helvetica">Select an option above
and use the buttons to scroll
through the images which will be displayed here.</FONT>

```

</BODY>

</HTML>

spectop.html

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>

    <META NAME="VPSiteProject"
CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp"><META HTTP-EQUIV="Content-Type"
CONTENT="text/html;CHARSET=iso-8859-1">
<SCRIPT LANGUAGE="JavaScript">
<!--
function specWrite() {
// Get the data
var JointLocation=document.specdata.JointLocation.value;
var JointTypeopt=document.specdata.JointType.selectedIndex;
var JointType=document.specdata.JointType.options[JointTypeopt].text;
var VerticalMovement=document.specdata.VerticalMovement.value;
var AxialMovement=document.specdata.AxialMovement.value;
var ShearMovement=document.specdata.ShearMovement.value;
var StaticGap=document.specdata.StaticGap.value;
var BaseFloorConstructionopt=document.specdata.BaseFloorConstruction.selectedIndex;
var
BaseFloorConstruction=document.specdata.BaseFloorConstruction.options[BaseFloorConstructionop
t].text;
var OtherFloorConstruction=document.specdata.OtherFloorConstruction.value;
var BaseWallConstructionopt=document.specdata.BaseWallConstruction.selectedIndex;
var
BaseWallConstruction=document.specdata.BaseWallConstruction.options[BaseWallConstructionopt].t
ext;
var OtherWallConstruction=document.specdata.OtherWallConstruction.value;
var FiraRating1=document.specdata.FiraRating1.value;
var FireRating2=document.specdata.FireRating2.value;
var FireRating3=document.specdata.FireRating3.value;
var JointExterioropt=document.specdata.JointExterior.selectedIndex;
var JointExterior=document.specdata.JointExterior.options[JointExterioropt].text;
var ExposedSurface11=document.specdata.ExposedSurface11.value;
var ExposedSurface2=document.specdata.ExposedSurface2.value;
var DurabilityYearsopt=document.specdata.DurabilityYears.selectedIndex;
var DurabilityYears=document.specdata.DurabilityYears.options[DurabilityYearsopt].text;
var AcousticRatingopt=document.specdata.AcousticRating.selectedIndex;
var AcousticRating=document.specdata.AcousticRating.options[AcousticRatingopt].text;
var OtherRequirements=document.specdata.OtherRequirements.value;

// Validate the data

var pf2d = parent.frames[2].document; // reduce the amount of typing to be done

//print results
pf2d.open();
pf2d.write('<BODY BGCOLOR="#FFFFFF" TEXT="#000000" LINK="#0000FF" VLINK="#800080"
ALINK="#FF0000">');
pf2d.write('<FONT FACE="Arial, Helvetica"><H2><FONT COLOR="green" FACE="Arial,
Helvetica">Seismic Joint Specification Sheet</font></H2>');
pf2d.write('<blockquote>');
pf2d.write('<blockquote>');
pf2d.write('<p ALIGN="JUSTIFY"></p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Joint location: ' + JointLocation + '</strong></p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Joint type: ' + JointType + '</strong></p>');
```

```

pf2d.write('<p ALIGN="JUSTIFY"><strong>Movement range:</strong></p>');
pf2d.write('<blockquote>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Vertical:</strong> <u>+ </u>' + VerticalMovement + '
mm</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Axial:</strong> <u>+ </u>' + AxialMovement + ' mm</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Shear</strong>: <u>+ </u>' + ShearMovement + '
mm</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Static gap</strong>: <u>+ </u>' + StaticGap + ' mm</p>');
pf2d.write('</blockquote>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Base floor construction:</strong>' +
BaseFloorConstruction + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Other floor construction:</strong>' +
OtherFloorConstruction + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Base wall construction:</strong>' + BaseWallConstruction
+ '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Other wall construction:</strong>' +
OtherWallConstruction + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Fire rating</strong>: FRR ' + FiraRating1 + ' / ' +
FireRating2 + ' / ' + FireRating3 + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Joint exterior</strong>: ' + JointExterior + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Exposed surface material 1.</strong>' +
ExposedSurface11 + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Exposed surface material 2.</strong>' +
ExposedSurface2 + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Durability (years) :</strong>' + DurabilityYears + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong>Acoustic requirements:</strong> STC ' + AcousticRating +
'</p>');
pf2d.write('<p ALIGN="JUSTIFY"><big>Other specific requirements:</big>');
pf2d.write('<p ALIGN="JUSTIFY">' + OtherRequirements + '</p>');
pf2d.write('<p ALIGN="JUSTIFY"><font FACE="Arial">&nbsp;</font></p>');
pf2d.write('<p ALIGN="JUSTIFY"><strong><font FACE="Arial">Labels to place on
joints</font></strong></p>');
pf2d.write('<p ALIGN="JUSTIFY"></p>');
pf2d.write('</blockquote>');
pf2d.write('</blockquote>');

```

```

pf2d.write('</BODY>');

```

```

pf2d.close();
}

```

```

//end -->
</SCRIPT>

```

```

<META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
<TITLE>Specification writer top</TITLE>

```

```

</HEAD>

```

```

<BODY BGCOLOR="white">

```

```

<FORM METHOD="GET" name="specdata" onSubmit="specWrite()">
<P>

```

```

<H1><A NAME="Joint"></A><FONT COLOR="#CC0000" FACE="Arial, Helvetica">Joint specification
writer</FONT></H1>

```

```

<P>

```

```

<TABLE BORDER="0" WIDTH="100%">

```

```

<TR>

```

```

<TD WIDTH="25%"><A NAME="Jointlocation"></A><B><FONT COLOR="black"
FACE="Arial, Helvetica">Joint location</FONT></B></TD>

```

```

        <TD WIDTH="45%"><INPUT TYPE="TEXT" NAME="JointLocation" SIZE="25"
MAXLENGTH="25"></TD>
        <TD WIDTH="16%"><A HREF="#Joint"><IMG SRC="images/b42.gif" WIDTH="40"
HEIGHT="43" ALIGN="BOTTOM" ALT="back" BORDER="0"></A></TD>
        <TD WIDTH="14%"><A HREF="#Jointtype"><IMG SRC="images/b38.gif"
WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next" BORDER="0"></A></TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>
<BR>
        </TD>
        <TD WIDTH="45%">&nbsp;</TD>
        <TD WIDTH="16%">&nbsp;</TD>
        <TD WIDTH="14%">&nbsp;</TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><A NAME="Jointtype"></A><B><FONT COLOR="black"
FACE="Arial, Helvetica">Joint type</FONT></B></TD>
        <TD WIDTH="45%">
            <SELECT NAME="JointType">
                <OPTION VALUE="Floor" SELECTED>Floor</OPTION>
                <OPTION VALUE="Wall">Wall</OPTION>
            </SELECT>
        </TD>
        <TD WIDTH="16%"><A HREF="#Jointlocation"><IMG SRC="images/b42.gif"
WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back" BORDER="0"></A></TD>
        <TD WIDTH="14%"><A HREF="#Verticalmovement"><IMG SRC="images/b38.gif"
WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next" BORDER="0"></A></TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>
<BR>
        </TD>
        <TD WIDTH="45%">&nbsp;</TD>
        <TD WIDTH="16%">&nbsp;</TD>
        <TD WIDTH="14%">&nbsp;</TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><A NAME="Verticalmovement"></A><B><FONT
COLOR="black" FACE="Arial, Helvetica">Vertical movement +/- (mm)</FONT></B></TD>
        <TD WIDTH="45%"><INPUT TYPE="TEXT" NAME="VerticalMovement" SIZE="4"
MAXLENGTH="4"></TD>
        <TD WIDTH="16%"><A HREF="#Jointtype"><IMG SRC="images/b42.gif"
WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back" BORDER="0"></A></TD>
        <TD WIDTH="14%"><A HREF="#Axialmovement"><IMG SRC="images/b38.gif"
WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next" BORDER="0"></A></TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>

```

```

<BR>
        </TD>
        <TD WIDTH="45%">&nbsp;</TD>
        <TD WIDTH="16%">&nbsp;</TD>
        <TD WIDTH="14%">&nbsp;</TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><A NAME="Axialmovement"></A><B><FONT COLOR="black"
FACE="Arial, Helvetica">Axial movement +/- (mm)</FONT></B></TD>
        <TD WIDTH="45%"><INPUT TYPE="TEXT" NAME="AxialMovement" SIZE="4"
MAXLENGTH="4"></TD>
        <TD WIDTH="16%"><A HREF="#Verticalmovement"><IMG SRC="images/b42.gif"
WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back" BORDER="0"></A></TD>
        <TD WIDTH="14%"><A HREF="#Shearmovement"><IMG SRC="images/b38.gif"
WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next" BORDER="0"></A></TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>
<BR>
        </TD>
        <TD WIDTH="45%">&nbsp;</TD>
        <TD WIDTH="16%">&nbsp;</TD>
        <TD WIDTH="14%">&nbsp;</TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><A NAME="Shearmovement"></A><B><FONT COLOR="black"
FACE="Arial, Helvetica">Shear movement +/- (mm)</FONT></B></TD>
        <TD WIDTH="45%"><INPUT TYPE="TEXT" NAME="ShearMovement" SIZE="4"
MAXLENGTH="4"></TD>
        <TD WIDTH="16%"><A HREF="#Axialmovement"><IMG SRC="images/b42.gif"
WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back" BORDER="0"></A></TD>
        <TD WIDTH="14%"><A HREF="#StaticGap"><IMG SRC="images/b38.gif"
WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next" BORDER="0"></A></TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>
<BR>
        </TD>
        <TD WIDTH="45%">&nbsp;</TD>
        <TD WIDTH="16%">&nbsp;</TD>
        <TD WIDTH="14%">&nbsp;</TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><A NAME="StaticGap"></A><B><FONT COLOR="black"
FACE="Arial, Helvetica">Static Gap +/- (mm)</FONT></B></TD>
        <TD WIDTH="45%"><INPUT TYPE="TEXT" NAME="StaticGap" SIZE="4"
MAXLENGTH="4"></TD>
        <TD WIDTH="16%"><A HREF="#Shearmovement"><IMG SRC="images/b42.gif"
WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back" BORDER="0"></A></TD>
        <TD WIDTH="14%"><A HREF="#Basewallconstruction"><IMG
SRC="images/b38.gif" WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next"
BORDER="0"></A></TD>
    </TR>

```

```

        <TR>
            <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>
<BR>
            </TD>
            <TD WIDTH="45%">&nbsp;</TD>
            <TD WIDTH="16%">&nbsp;</TD>
            <TD WIDTH="14%">&nbsp;</TD>
        </TR>
        <TR>
            <TD WIDTH="25%"><A NAME="Basefloorconstruction"></A><B><FONT
COLOR="black" FACE="Arial, Helvetica">Base floor construction</FONT></B></TD>
            <TD WIDTH="45%">
                <SELECT NAME="BaseFloorConstruction">
                <OPTION SELECTED>Concrete</OPTION>
                <OPTION>Timber stud</OPTION>
                <OPTION>Metal stud</OPTION>
                <OPTION>Other</OPTION>
                </SELECT>
            </TD>
            <TD WIDTH="16%"><A HREF="#StaticGap"><IMG SRC="images/b42.gif"
WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back" BORDER="0"></A></TD>
            <TD WIDTH="14%"><A HREF="#Othertypeoffloorconstructio"><IMG
SRC="images/b38.gif" WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next"
BORDER="0"></A></TD>
        </TR>
        <TR>
            <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>
<BR>
            </TD>
            <TD WIDTH="45%">&nbsp;</TD>
            <TD WIDTH="16%">&nbsp;</TD>
            <TD WIDTH="14%">&nbsp;</TD>
        </TR>
        <TR>
            <TD WIDTH="25%"><A NAME="Othertypeoffloorconstructio"></A><B><FONT
COLOR="black" FACE="Arial, Helvetica">Other type of floor construction</FONT></B></TD>
            <TD WIDTH="45%"><INPUT TYPE="TEXT" NAME="OtherFloorConstruction"
SIZE="25" MAXLENGTH="25"></TD>
            <TD WIDTH="16%"><A HREF="#Basefloorconstruction"><IMG
SRC="images/b42.gif" WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back"
BORDER="0"></A></TD>
            <TD WIDTH="14%"><A HREF="#Basewallconstruction"><IMG
SRC="images/b38.gif" WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next"
BORDER="0"></A></TD>
        </TR>
        <TR>
            <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>
<BR>
            </TD>

```



```

        <TD WIDTH="45%">&nbsp;</TD>
        <TD WIDTH="16%">&nbsp;</TD>
        <TD WIDTH="14%">&nbsp;</TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><A NAME="Basewallconstruction"></A><B><FONT
COLOR="black" FACE="Arial, Helvetica">Base wall construction</FONT></B></TD>
        <TD WIDTH="45%">
            <SELECT NAME="BaseWallConstruction">
                <OPTION SELECTED>Concrete</OPTION>
                <OPTION>Timber stud</OPTION>
                <OPTION>Metal stud</OPTION>
                <OPTION>Other</OPTION>
            </SELECT>
        </TD>
        <TD WIDTH="16%"><A HREF="#Othertypeoffloorconstructio"><IMG
SRC="images/b42.gif" WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back"
BORDER="0"></A></TD>
        <TD WIDTH="14%"><A HREF="#Othertypeofwallconstruction"><IMG
SRC="images/b38.gif" WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next"
BORDER="0"></A></TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><BR>
        <BR>
        <BR>
        <BR>
        <BR>
        </TD>
        <TD WIDTH="45%">&nbsp;</TD>
        <TD WIDTH="16%">&nbsp;</TD>
        <TD WIDTH="14%">&nbsp;</TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><A NAME="Othertypeofwallconstruction"></A><B><FONT
COLOR="black" FACE="Arial, Helvetica">Other type of wall construction</FONT></B></TD>
        <TD WIDTH="45%"><INPUT TYPE="TEXT" NAME="OtherWallConstruction"
SIZE="25" MAXLENGTH="25"></TD>
        <TD WIDTH="16%"><A HREF="#Basewallconstruction"><IMG
SRC="images/b42.gif" WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back"
BORDER="0"></A></TD>
        <TD WIDTH="14%"><A HREF="#FireRatingFRR"><IMG SRC="images/b38.gif"
WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next" BORDER="0"></A></TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><BR>
        <BR>
        <BR>
        <BR>
        <BR>
        </TD>
        <TD WIDTH="45%">&nbsp;</TD>
        <TD WIDTH="16%">&nbsp;</TD>
        <TD WIDTH="14%">&nbsp;</TD>
    </TR>
    <TR>
        <TD WIDTH="25%"><A NAME="FireRatingFRR"></A><B><FONT COLOR="black"
FACE="Arial, Helvetica">Fire Rating FRR:</FONT></B></TD>

```

```

                <TD WIDTH="45%"><INPUT TYPE="TEXT" NAME="FiraRating1" SIZE="3"
MAXLENGTH="3"><FONT COLOR="black" FACE="Arial, Helvetica"></INPUT
                TYPE="TEXT" NAME="FireRating2" SIZE="3" MAXLENGTH="3"></INPUT
                TYPE="TEXT" NAME="FireRating3" SIZE="3" MAXLENGTH="3"></FONT></TD>
                <TD WIDTH="16%"><A HREF="#Othertypeofwallconstruction"><IMG
                SRC="images/b42.gif" WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back"
                BORDER="0"></A></TD>
                <TD WIDTH="14%"><A HREF="#Jointexterior"><IMG SRC="images/b38.gif"
                WIDTH="42" HEIGHT="43" ALIGN="BOTTOM" ALT="next" BORDER="0"></A></TD>
        </TR>
        <TR>
                <TD WIDTH="25%"><BR>
<BR>
<BR>
<BR>
<BR>
                </TD>
                <TD WIDTH="45%">&nbsp;</TD>
                <TD WIDTH="16%">&nbsp;</TD>
                <TD WIDTH="14%">&nbsp;</TD>
        </TR>
        <TR>
                <TD WIDTH="25%"><A NAME="Jointexterior"></A><B><FONT COLOR="black"
                FACE="Arial, Helvetica">Joint exterior:</FONT></B></TD>
                <TD WIDTH="45%">
                        <SELECT NAME="JointExterior">
                                <OPTION SELECTED>Concealed</OPTION>
                                <OPTION>Exposed</OPTION>
                        </SELECT>
                </TD>
                <TD WIDTH="16%"><A HREF="#FireRatingFRR"><IMG SRC="images/b42.gif"
                WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back" BORDER="0"></A></TD>
                <TD WIDTH="14%"><A HREF="#Exposedsurfacematerial1"><IMG
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        <TR>
                <TD WIDTH="25%"><BR>
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                <TD WIDTH="45%">&nbsp;</TD>
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                <TD WIDTH="16%"><A HREF="#Jointexterior"><IMG SRC="images/b42.gif"
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                <TD WIDTH="14%"><A HREF="#Exposedsurfacematerial2"><IMG
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```

        <TD WIDTH="25%"><BR>
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        <TD WIDTH="25%"><A NAME="Durabilityyears"></A><B><FONT COLOR="black"
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                <OPTION>20</OPTION>
                <OPTION>50</OPTION>
                <OPTION>75</OPTION>
                <OPTION>100</OPTION>
            </SELECT>
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        <TD WIDTH="16%">&nbsp;</TD>
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    <TR>
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SRC="images/b42.gif" WIDTH="40" HEIGHT="43" ALIGN="BOTTOM" ALT="back"
BORDER="0"></FONT></A><FONT COLOR="black"
FACE="Arial, Helvetica"> | </FONT><A HREF="#Go!"><FONT COLOR="black" FACE="Arial,
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<P><TEXTAREA NAME="OtherRequirements" ROWS="7" COLS="56"></TEXTAREA></P>

<P><A NAME="Go!"></A><A HREF="javascript:specWrite()"><B><FONT COLOR="#009900"
FACE="Arial, Helvetica">Go!</FONT></B></A>
</FORM>

</BODY>

</HTML>

```

specbottom.html

```

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 3.2//EN">
<HTML>

<HEAD>
    <META HTTP-EQUIV="Content-Type" CONTENT="text/html;CHARSET=iso-8859-1">
    <META NAME="VPSiteProject" CONTENT="file:///F:/DataFiles/Disert/website/seismic.vpp">

    <META NAME="GENERATOR" Content="Visual Page 2.0 for Windows">
    <TITLE>spec bottom</TITLE>
</HEAD>

<BODY BGCOLOR="white">

<P></P>

<P><BR>
<BR>
<BR>

```


</P>

<H3 ALIGN="CENTER">Answer the questions
above about your seismic
joint then press go at the end for a customised seismic joint specification to appear here!

</BODY>

</HTML>

DynEl.js

```
// This example is from JavaScript: The Definitive Guide, 3rd Edition.
// That book and this example were Written by David Flanagan.
// They are Copyright (c) 1996, 1997, 1998 O'Reilly & Associates.
// This example is provided WITHOUT WARRANTY either expressed or implied.
// You may study, use, modify, and distribute it for any purpose,
// as long as this notice is retained.
```

```
/*
 * File: DynEl.js
 * Include with: <SCRIPT SRC="DynEl.js"></SCRIPT>
 *
 * This file defines the DynEl class, which provides a portable API
 * to many Dynamic HTML features.
 */

/*
 * This is the constructor function for DynEl objects.
 * The arguments are the following:
 * window: The Window object in which the dynamic element is to appear
 * id: The HTML ID for the dynamic element. Must be unique.
 * body: HTML text that constitutes the body of the dynamic element
 * left: The optional initial X-coordinate of the element
 * top: The optional initial Y-coordinate of the element
 * width: The optional width of the element
 *
 * This constructor outputs a style sheet into the current document.
 * This means that it can only be called from the <HEAD> of the document
 * before any text has been output for display.
 */
```

```
function DynEl(window, id, body, left, top, width) {
    // Remember some arguments for later.
    this.window = window;
    this.id = id;
    this.body = body;

    // Output a CSS-P style sheet for this element.
    var d = window.document;
    d.writeln('<STYLE TYPE="text/css">');
    d.write('#' + id + ' {position:absolute;}');
    if (left) d.write('left:' + left + ';');
    if (top) d.write('top:' + top + ';');
    if (width) d.write('width:' + width + ';');
    d.writeln('}');
    d.writeln('</STYLE>');
}
```

```
/*
 * Now we define a bunch of methods for the DynEl class.
 * We define one set of methods if we are running in Navigator, and
 * another set of methods if we are running in Internet Explorer.
 * Note that the APIs of the methods are the same in both cases; it
 * is only the method bodies that change. In this way, we define
 * a portable API to the common DHTML functionality of the two browsers.
 */
```

```
// First, define the Navigator methods.
if (navigator.appName.indexOf("Netscape") != -1) {
```

```
/*
```

- * This function outputs the dynamic element itself into the document.
- * It must be called before any other methods of the DynEl object can be used.

```

*/
DynEl.prototype.output = function() {
    var d = this.window.document; // Shortcut variable: saves typing

    // Output the element within a <DIV> tag. Specify the element id.
    d.writeln('<DIV ID="' + this.id + '">');
    d.writeln(this.body);
    d.writeln('</DIV>');

    // Now, for convenience, save a reference to the Layer object
    // created by this dynamic element.
    this.layer = d[this.id];
}

// Here are methods for moving, hiding, stacking, and otherwise
// manipulating the dynamic element.
DynEl.prototype.moveTo = function(x,y) { this.layer.moveTo(x,y); }
DynEl.prototype.moveBy = function(x,y) { this.layer.moveBy(x,y); }
DynEl.prototype.show = function() { this.layer.visibility = "show"; }
DynEl.prototype.hide = function() { this.layer.visibility = "hide"; }
DynEl.prototype.setStackingOrder = function(z) { this.layer.zIndex = z; }
DynEl.prototype.setBgColor = function(color) {
    this.layer.bgColor = color;
}
DynEl.prototype.setBgImage = function(image) {
    this.layer.background.src = image;
}

// These methods query the position, size, and other properties
// of the dynamic element.
DynEl.prototype.getX = function() { return this.layer.left; }
DynEl.prototype.getY = function() { return this.layer.right; }
DynEl.prototype.getWidth = function() { return this.layer.width; }
DynEl.prototype.getHeight = function() { return this.layer.height; }
DynEl.prototype.getStackingOrder = function() { return this.layer.zIndex; }
DynEl.prototype.isVisible = function() {
    return this.layer.visibility == "show";
}

/*
* This method allows us to dynamically change the contents of
* the dynamic element. The argument or arguments should be HTML
* strings which become the new body of the element.
*/
DynEl.prototype.setBody = function() {
    for(var i = 0; i < arguments.length; i++)
        this.layer.document.writeln(arguments[i]);
    this.layer.document.close();
}

/*
* This method registers a handler for the named event on the
* element. The event name argument should be the name of an
* event handler property, such as "onmousedown" or "onkeypress".
* The handler is a function that takes whatever action is necessary.
* Because Navigator and IE do not have compatible Event objects,
* all event details are passed as arguments to the handler function.
* When invoked, the handler will be passed the following nine arguments:

```

```

* 1) A reference to the DynEl object
* 2) A string containing the event type
* 3) The X-coordinate of the mouse, relative to the DynEl
* 4) The Y-coordinate of the mouse.
* 5) The mouse button that was clicked (if any)
* 6) The Unicode code of the key that was pressed (if any)
* 7) A boolean specifying whether the Shift key was down
* 8) A boolean specifying whether the Control key was down
* 9) A boolean specifying whether the Alt key was down
* Event handlers that are not interested in all these arguments do
* not have to declare them all in their argument lists, of course.
*/
DynEl.prototype.addEventHandler = function(eventname, handler) {
    // Arrange to capture events on this layer.
    this.layer.captureEvents(DynEl._eventmasks[eventname]);
    var dynel = this; // Current DynEl for use in the nested function.
    // Define an event handler that will invoke the specified handler,
    // and pass it the nine arguments specified above.
    this.layer[eventname] = function(event) {
        return handler(dynel, event.type, event.x, event.y,
            event.which, event.which,
            ((event.modifiers & Event.SHIFT_MASK) != 0),
            ((event.modifiers & Event.CTRL_MASK) != 0),
            ((event.modifiers & Event.ALT_MASK) != 0));
    }
}

/*
* This method unregisters the named event handler. It should be
* called with a single string argument such as "onmouseover".
*/
DynEl.prototype.removeEventHandler = function(eventname) {
    this.layer.releaseEvents(DynEl._eventmasks[eventname]);
    delete this.layer[eventname];
}

/*
* This array is used internally by the two methods above to map
* from event name to event type.
*/
DynEl._eventmasks = {
    onabort:Event.ABORT, onblur:Event.BLUR, onchange:Event.CHANGE,
    onclick:Event.CLICK, ondblclick:Event.DBLCLICK,
    ondragdrop:Event.DRAGDROP, onerror:Event.ERROR,
    onfocus:Event.FOCUS, onkeydown:Event.KEYDOWN,
    onkeypress:Event.KEYPRESS, onkeyup:Event.KEYUP, onload:Event.LOAD,
    onmousedown:Event.MOUSEDOWN, onmousemove:Event.MOUSEMOVE,
    onmouseout:Event.MOUSEOUT, onmouseover:Event.MOUSEOVER,
    onmouseup:Event.MOUSEUP, onmove:Event.MOVE, onreset:Event.RESET,
    onresize:Event.RESIZE, onselect:Event.SELECT, onsubmit:Event.SUBMIT,
    onunload:Event.UNLOAD
};

/*
* Now define methods for Internet Explorer.
* These methods have identical APIs to the ones defined for Netscape
* above. Therefore, we will not repeat all the comments above.
*/
if (navigator.appName.indexOf("Microsoft") != -1) {

```



```

// The all-important output() method
DynEl.prototype.output = function() {
    var d = this.window.document; // Shortcut variable: saves typing

    // Output the element within a <DIV> tag. Specify the element id.
    d.writeln("<DIV ID=\"" + this.id + "\">");
    d.writeln(this.body);
    d.writeln("</DIV>");

    // Now, for convenience, save references to the <DIV> element
    // we've created, and to its associated Style element.
    // These will be used throughout the methods that follow.
    this.element = d.all[this.id];
    this.style = this.element.style;
}

// Methods to move the dynamic object
DynEl.prototype.moveTo = function(x,y) {
    this.style.pixelLeft = x;
    this.style.pixelTop = y;
}
DynEl.prototype.moveBy = function(x,y) {
    this.style.pixelLeft += x;
    this.style.pixelTop += y;
}

// Methods to set other attributes of the dynamic object
DynEl.prototype.show = function() { this.style.visibility = "visible"; }
DynEl.prototype.hide = function() { this.style.visibility = "hidden"; }
DynEl.prototype.setStackingOrder = function(z) { this.style.zIndex = z; }
DynEl.prototype.setBgColor = function(color) {
    this.style.backgroundColor = color;
}
DynEl.prototype.setBgImage = function(image) {
    this.style.backgroundImage = image;
}

// Methods to query the dynamic object
DynEl.prototype.getX = function() { return this.style.pixelLeft; }
DynEl.prototype.getY = function() { return this.style.pixelTop; }
DynEl.prototype.getWidth = function() { return this.style.width; }
DynEl.prototype.getHeight = function() { return this.style.height; }
DynEl.prototype.getStackingOrder = function() { return this.style.zIndex; }
DynEl.prototype.isVisible = function() {
    return this.style.visibility == "visible";
}

// Change the contents of the dynamic element.
DynEl.prototype.setBody = function() {
    var body = "";
    for(var i = 0; i < arguments.length; i++) {
        body += arguments[i] + "\n";
    }
    this.element.innerHTML = body;
}

// Define an event handler.
DynEl.prototype.addEventHandler = function(eventname, handler) {
    var dynel = this; // Current DynEl for use in the nested function
    // Set an IE4 event handler that invokes the specified handler
    // with the appropriate nine arguments.

```

```

this.element[eventname] = function() {
    var e = dynel.window.event;
    e.cancelBubble = true;
    return handler(dynel, e.type, e.x, e.y,
        e.button, e.keyCode,
        e.shiftKey, e.ctrlKey, e.altKey);
}
}

// Remove an event handler.
DynEl.prototype.removeEventHandler = function(eventname) {
    delete this.element[eventname];
}
}

```

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